IPv6 Motivations and Obstacles

Lee Howard

Retevia

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Agenda

- Economic Drivers
- Cool new technologies
- External Factors
- Perceived obstacles
- Top obstacles
- IPv6-only

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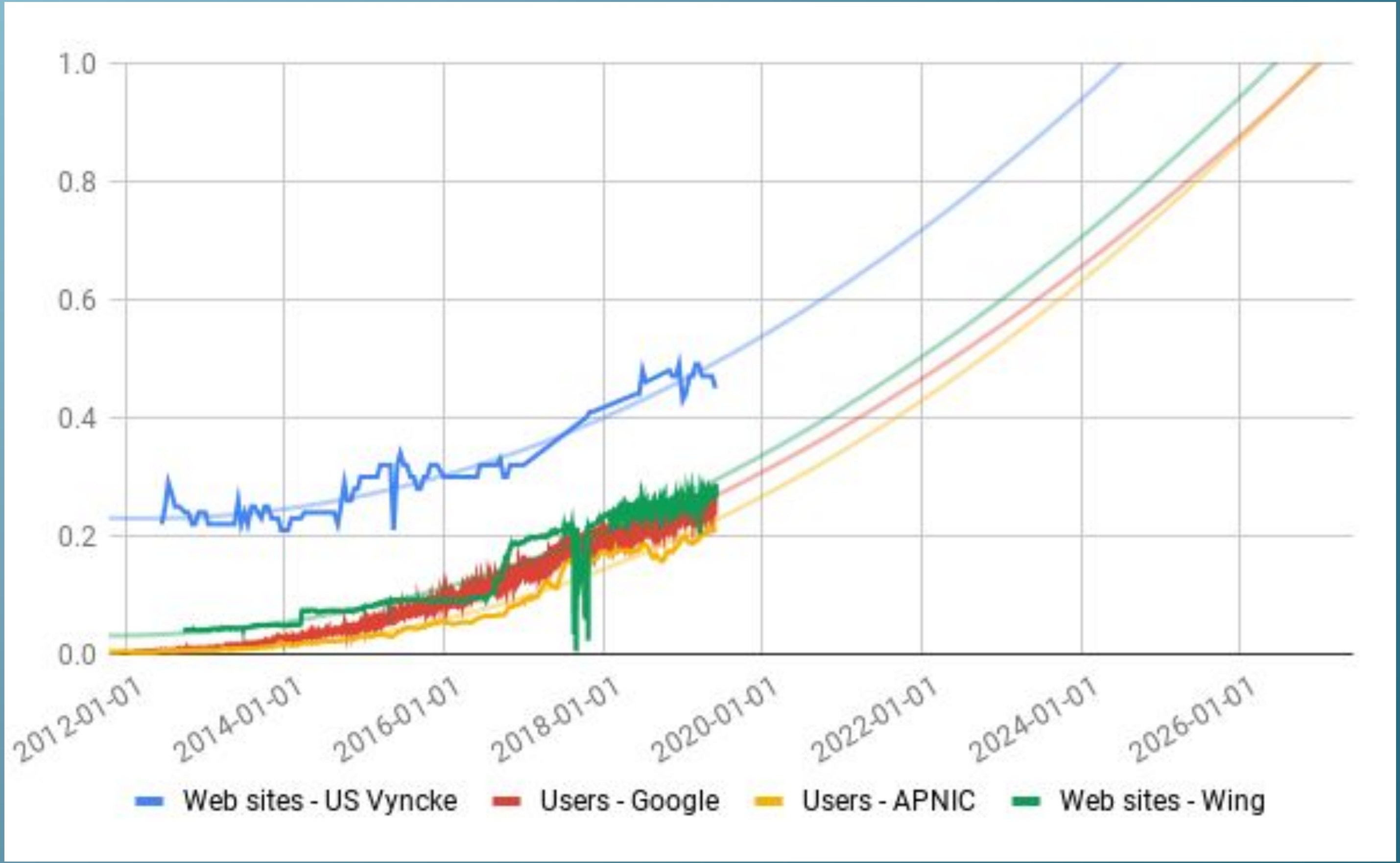
IPv6 Growth



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Economic Drivers

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IPv6 Speed

APNIC 2013	IPv6 is faster more often than IPv4 is.
Cisco 2014	IPv6 is faster more often than IPv4 is.
TWC 2014	IPv6 is 10% faster on average.
Akamai 2016	(iPhone/VzW) 95% sites are 15% faster.
LinkedIn 2016	IPv6 is often 15-25% faster.
Facebook 2017	IPv6 is 30-40% (or less) faster.
Bajpai, Schönwälder 2017	95% of sites are same or faster.
APNIC yesterday	In most regions, IPv6 is 20ms faster.

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Value of a Millisecond

"Every 100ms of latency costs 1% in Sales"

Amazon

"100-millisecond delay in website load time can hurt conversion rates by 7%"

Akamai

Google

"Traffic and revenue ... dropped by 20%. . . Half a second delay caused a 20% drop in traffic."

https://www.retevia.net/seo/

Value of a Millisecond

20ms =
+ 0.2% in sales
= $400 million

Amazon

20ms =
+ 1.4% in sales =
$38 million

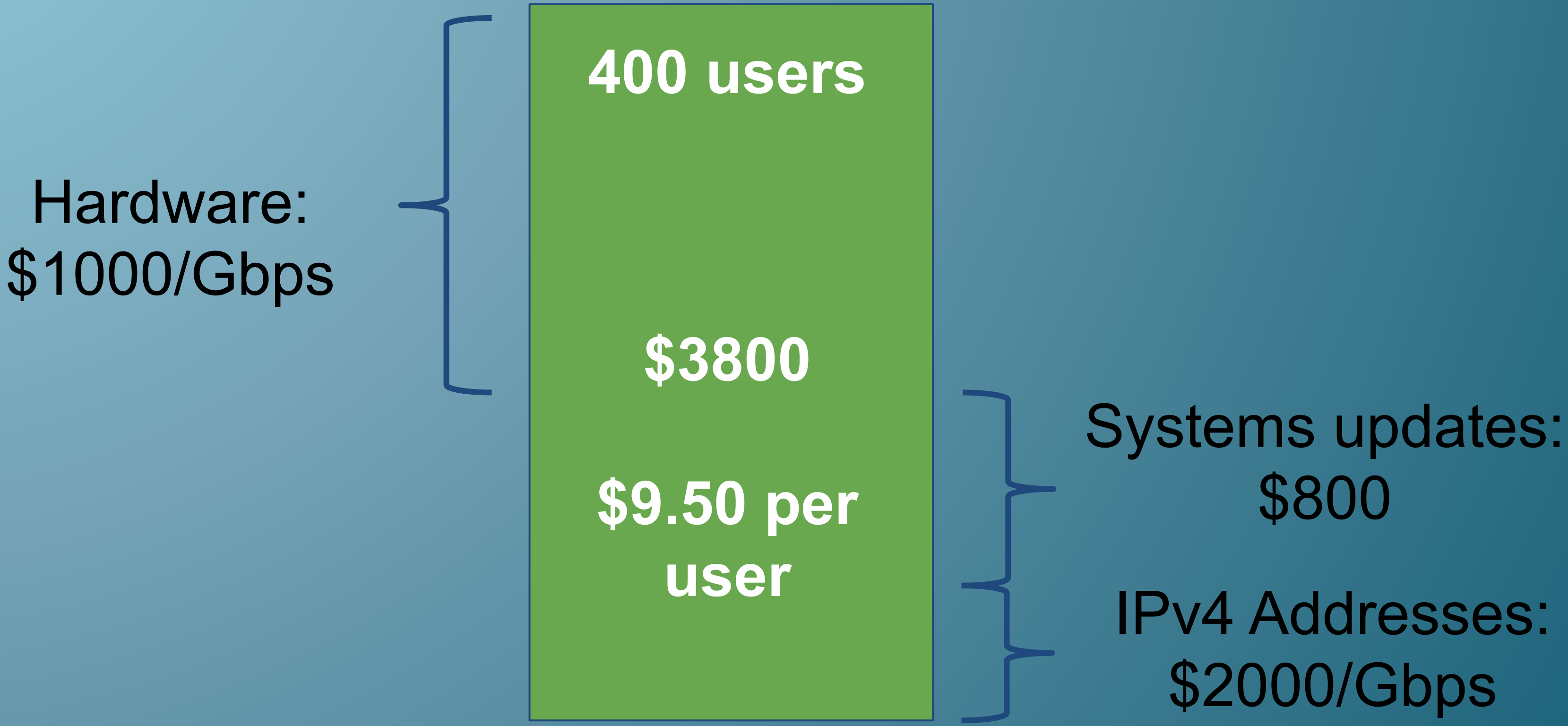
Akamai

Google

½ sec = 20% in revenue
= $1.1 billion

https://www.retevia.net/prisoner/

Cost of CGN



Hardware:
$1000/Gbps

400 users

$3800

$9.50 per user

Systems updates:
$800

IPv4 Addresses:
$2000/Gbps

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Technology Drivers

PDM

- Sender includes in a DestinationOptions Header:
  - Packet Sequence # this packet
  - Packet Sequence # last received
  - Time between last packet sent and last received
  - Time between last packet received and last sent
- Allows you to determine RTT and server delay

rfc8250 “IPv6 Performance and Diagnostic Metrics (PDM) Destination Option”
Ackermann et al.

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M-PDM

- If implemented, will provide:
  - Delay generated by this host
  - Delay generated by remote host
  - Sequence numbers for reading in packet captures
- Proposed HBH option will let middleboxes add their own information

https://tools.ietf.org/html/draft-fear-ippm-mpdm-01 combines rfc8250 “IPv6 Performance and Diagnotic Metrics (PDM) Destination Option” and rfc8321 “Alternate-Marking Method for Passive and Hybrid Performance Monitoring”

Reserving Bits

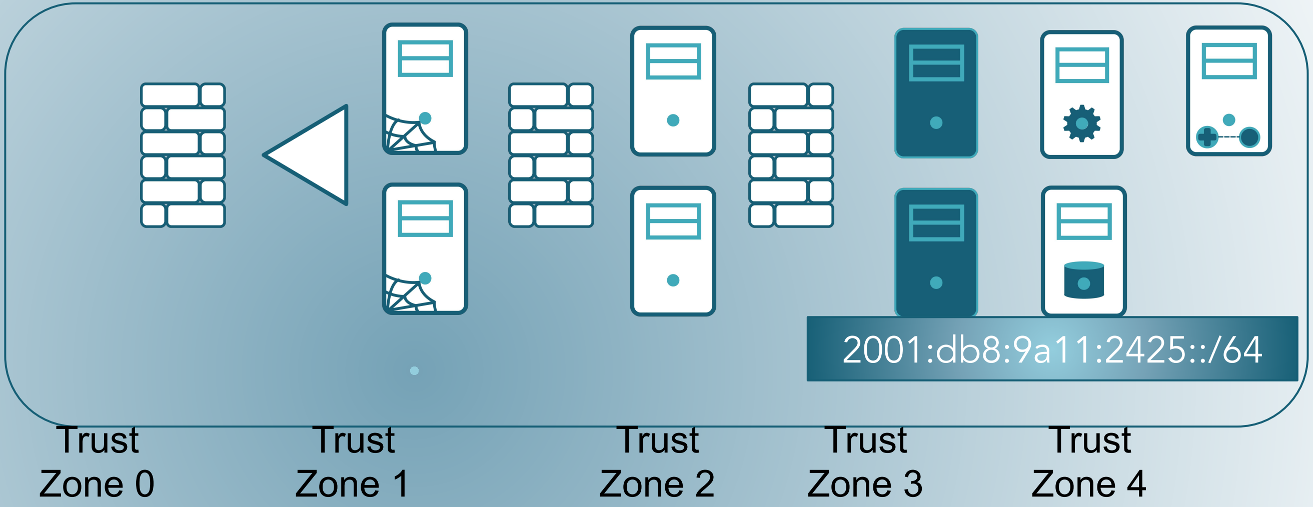
2001:db8:xxRR::/48
2001:db8:xxRR:DTAA::/64

R = Region 0-255

D = Data Center 0-15

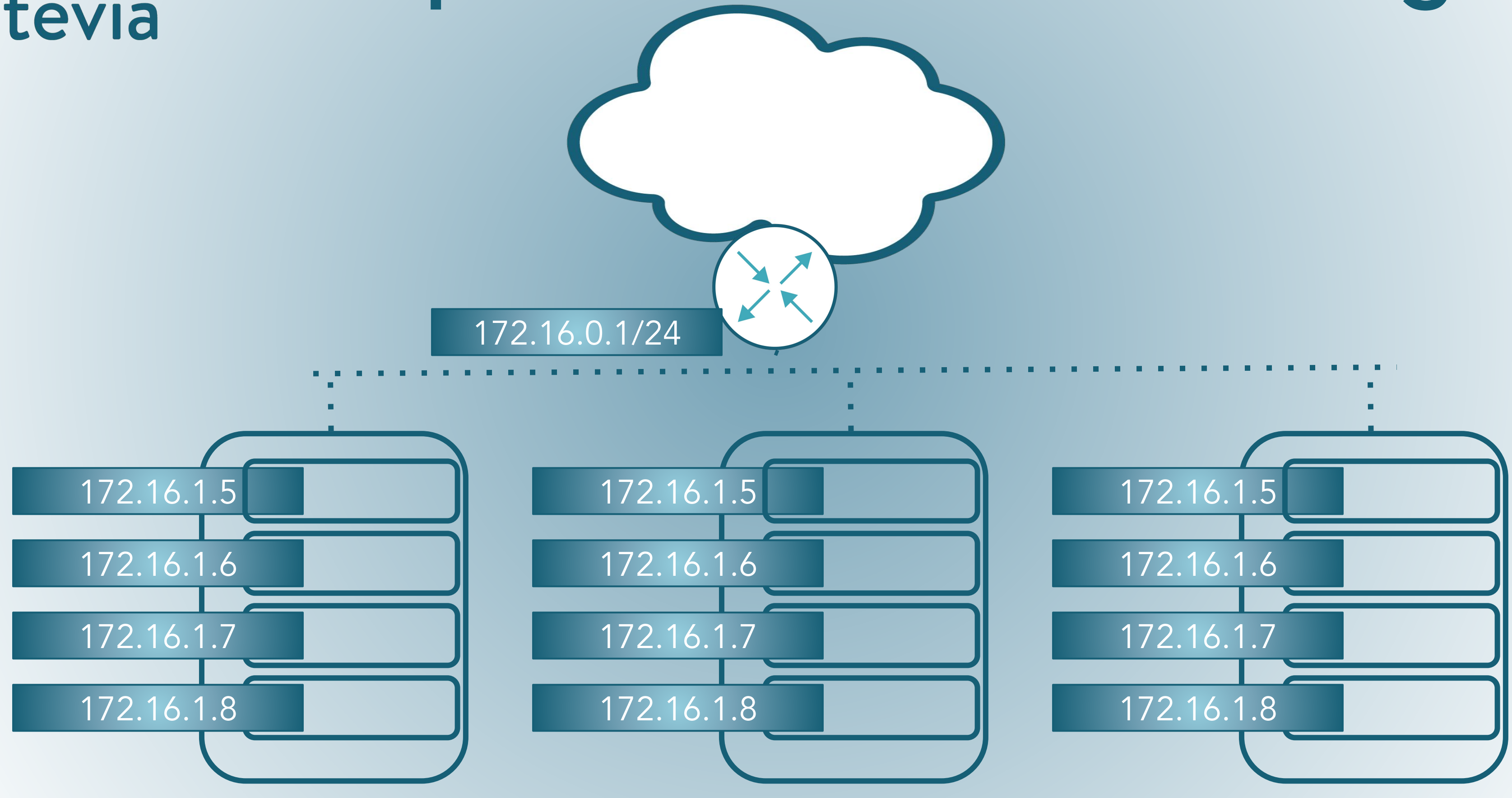
T = Trust Zone 0-15

AA = Application 0-255

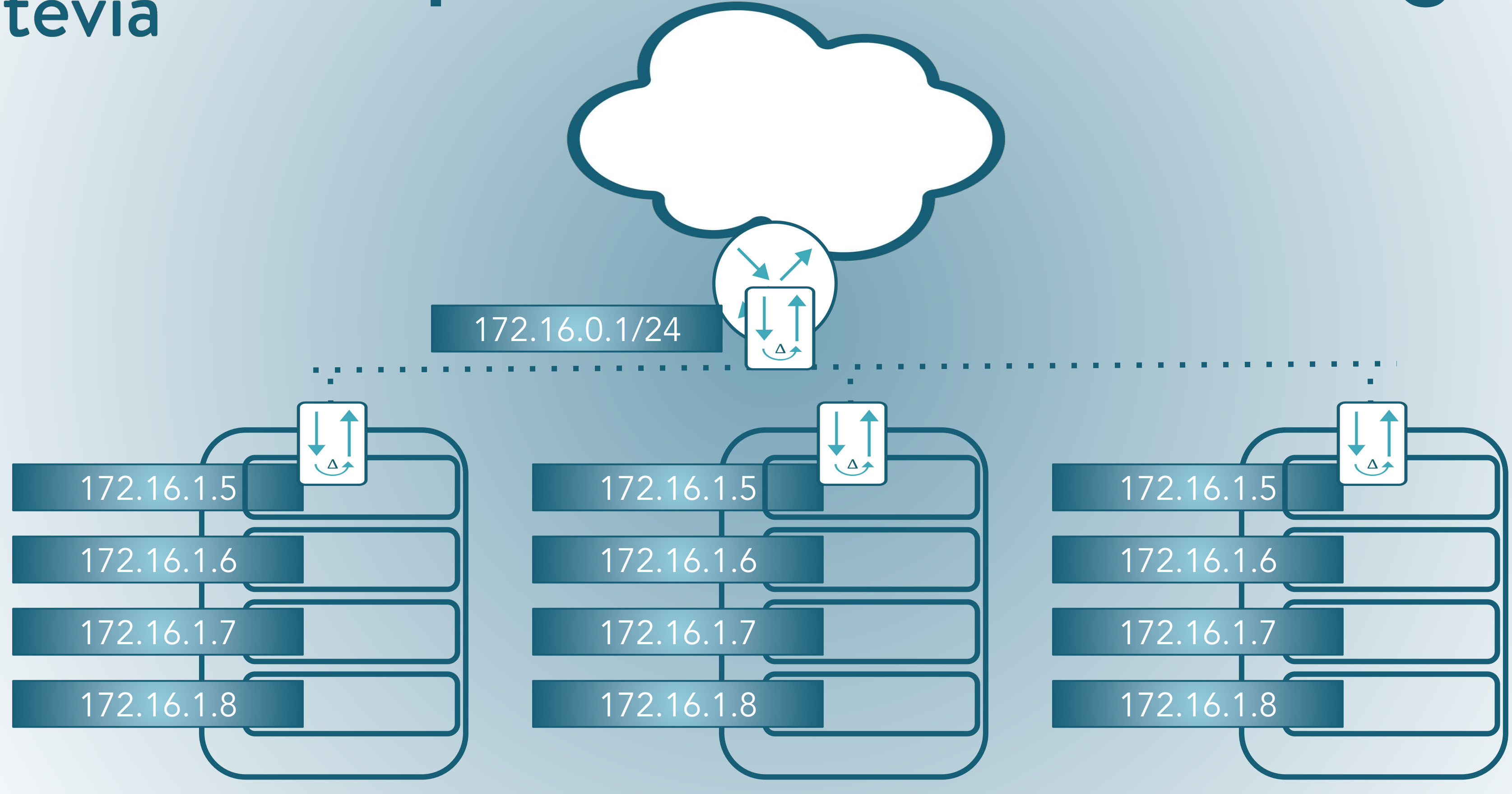


Region 17 (0x11), Data Center 2,
Trust Zone 4, Application 25
2001:db8:9a11:2425:0123:4567:89ab:cdef

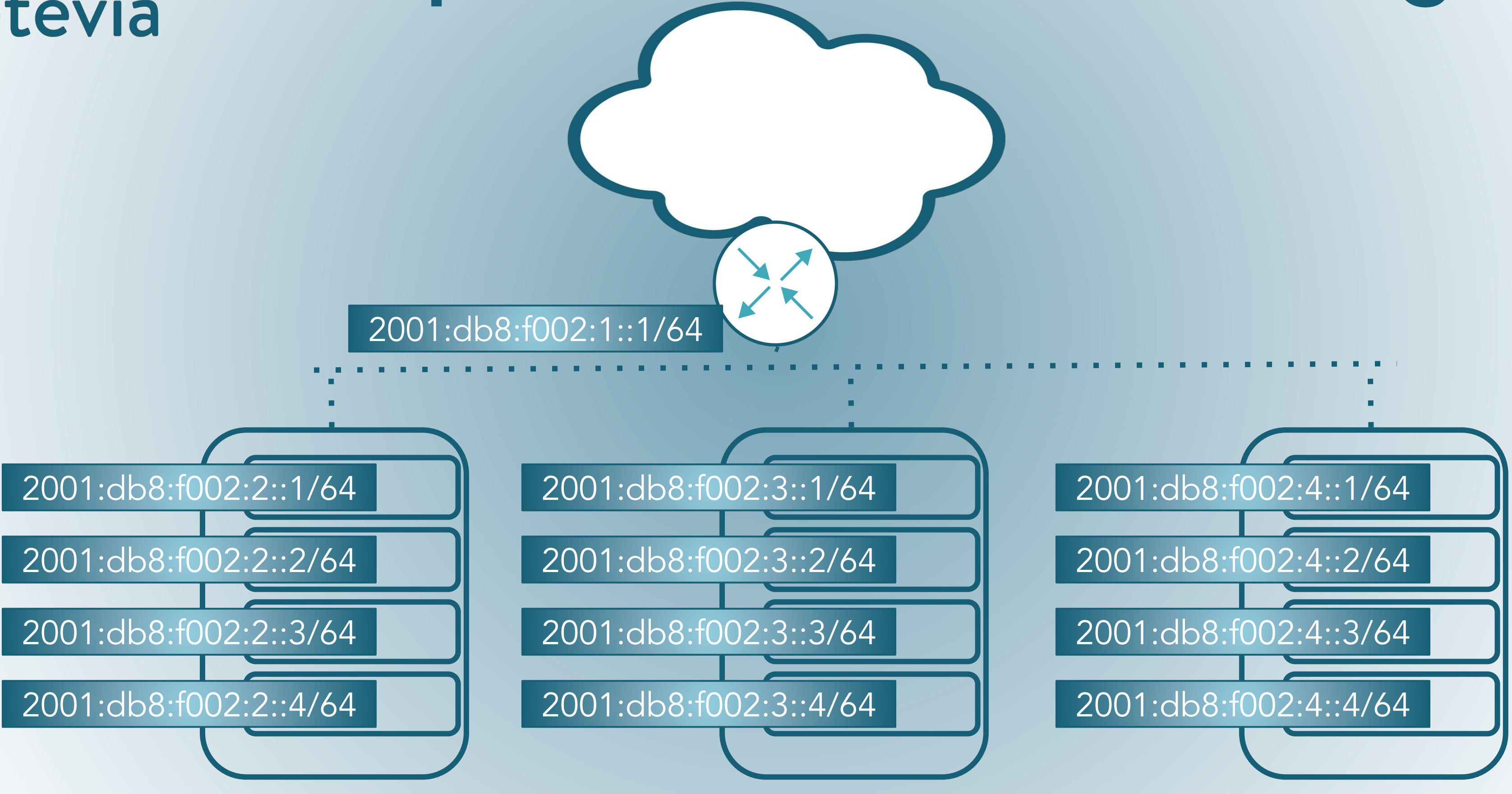
Simpler Container Numbering



Simpler Container Numbering



Simpler Container Numbering



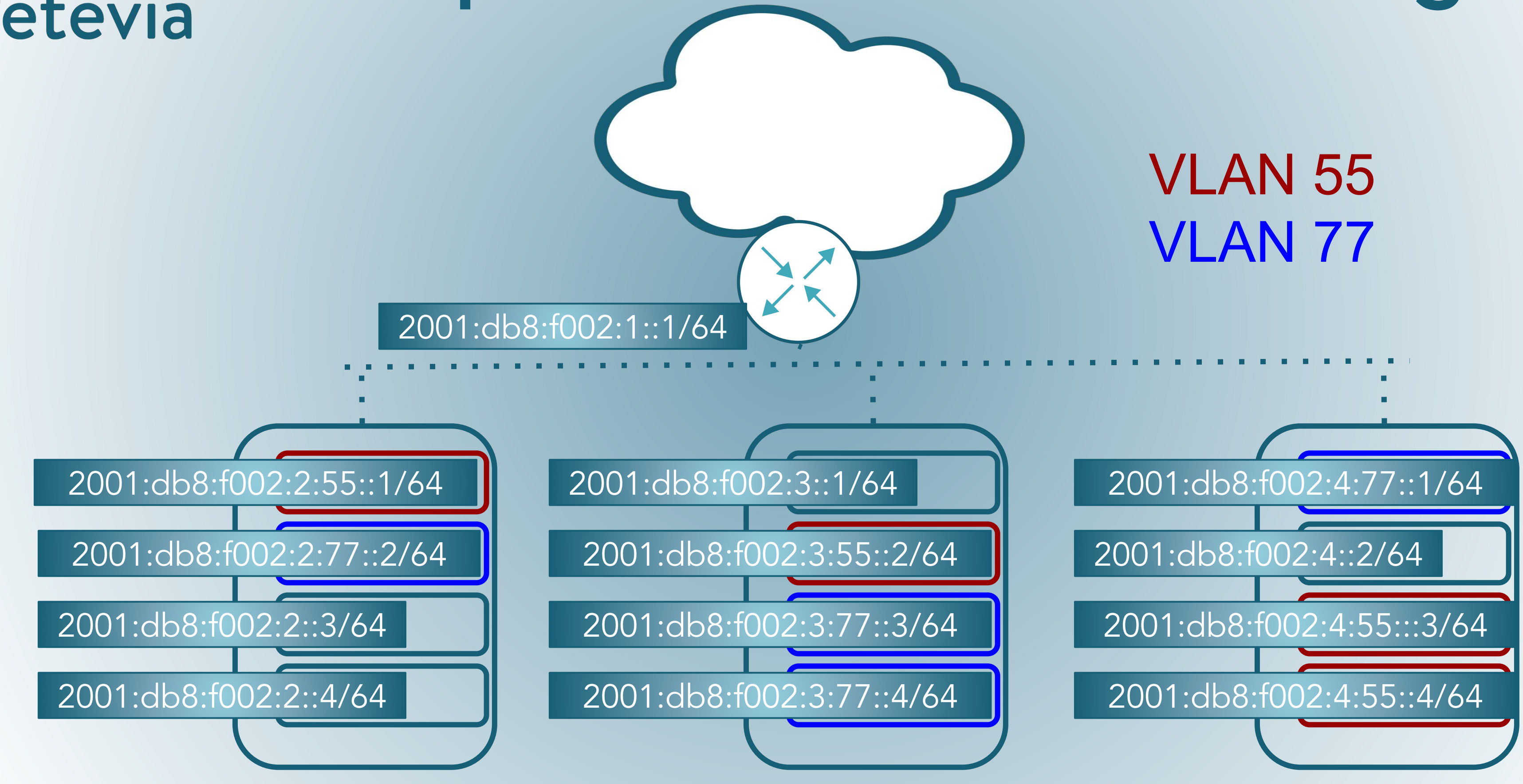
2001:db8:f002:1::1/64

2001:db8:f002:2::1/64
2001:db8:f002:2::2/64
2001:db8:f002:2::3/64
2001:db8:f002:2::4/64

2001:db8:f002:3::1/64
2001:db8:f002:3::2/64
2001:db8:f002:3::3/64
2001:db8:f002:3::4/64

2001:db8:f002:4::1/64
2001:db8:f002:4::2/64
2001:db8:f002:4::3/64
2001:db8:f002:4::4/64

Simpler Container Numbering



VLAN 55

VLAN 77

2001:db8:f002:1::1/64

2001:db8:f002:2:55::1/64

2001:db8:f002:2:77::2/64

2001:db8:f002:2::3/64

2001:db8:f002:2::4/64

2001:db8:f002:3::1/64

2001:db8:f002:3:55::2/64

2001:db8:f002:3:77::3/64

2001:db8:f002:3:77::4/64

2001:db8:f002:4:77::1/64

2001:db8:f002:4::2/64

2001:db8:f002:4:55:::3/64

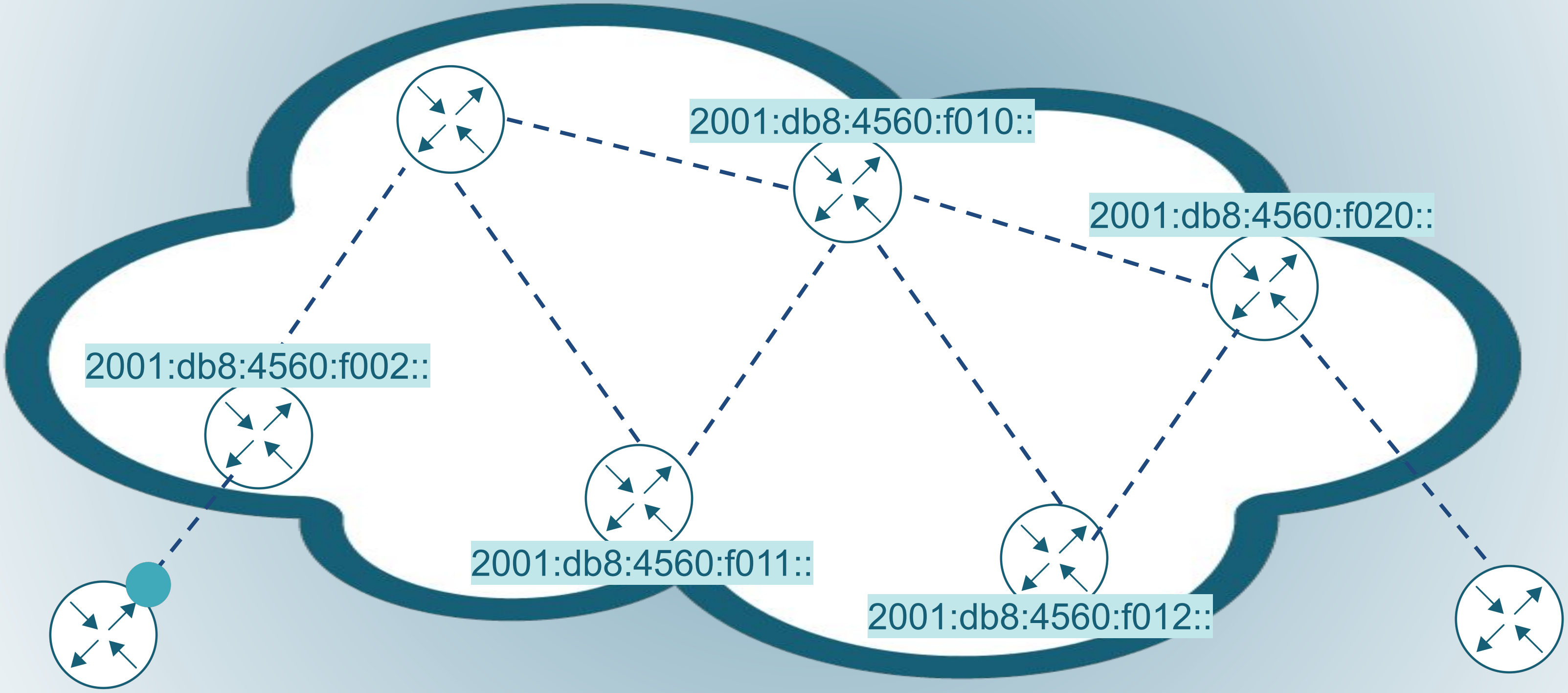
2001:db8:f002:4:55::4/64

Finer Control over Routing

Sometimes

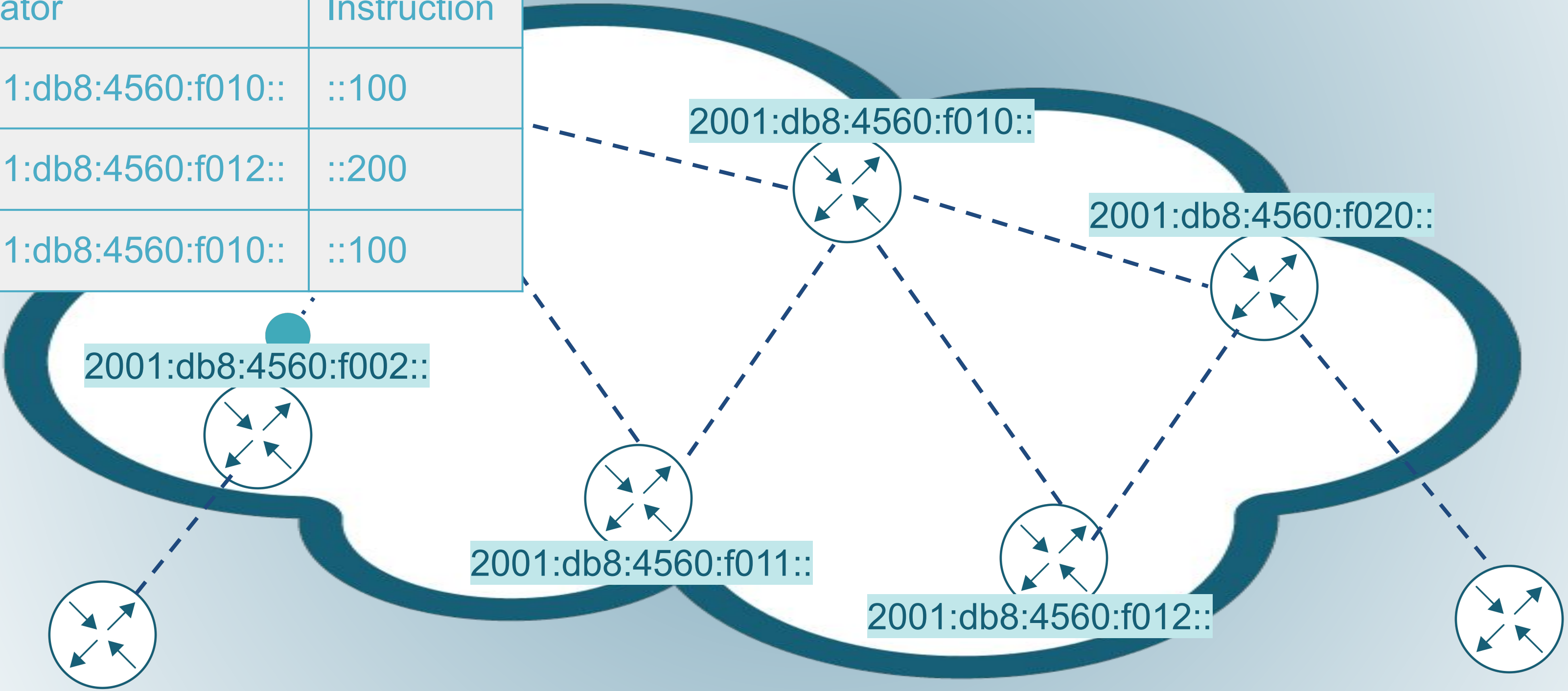
- "best path" != "shortest path"
- You want to abstract the path
- You want to avoid per-flow state
- You want to have a backup route pre-calculated (FRR)
- Lots of protocols make things complicated
- You want NFV

Segment Routing (SRv6)



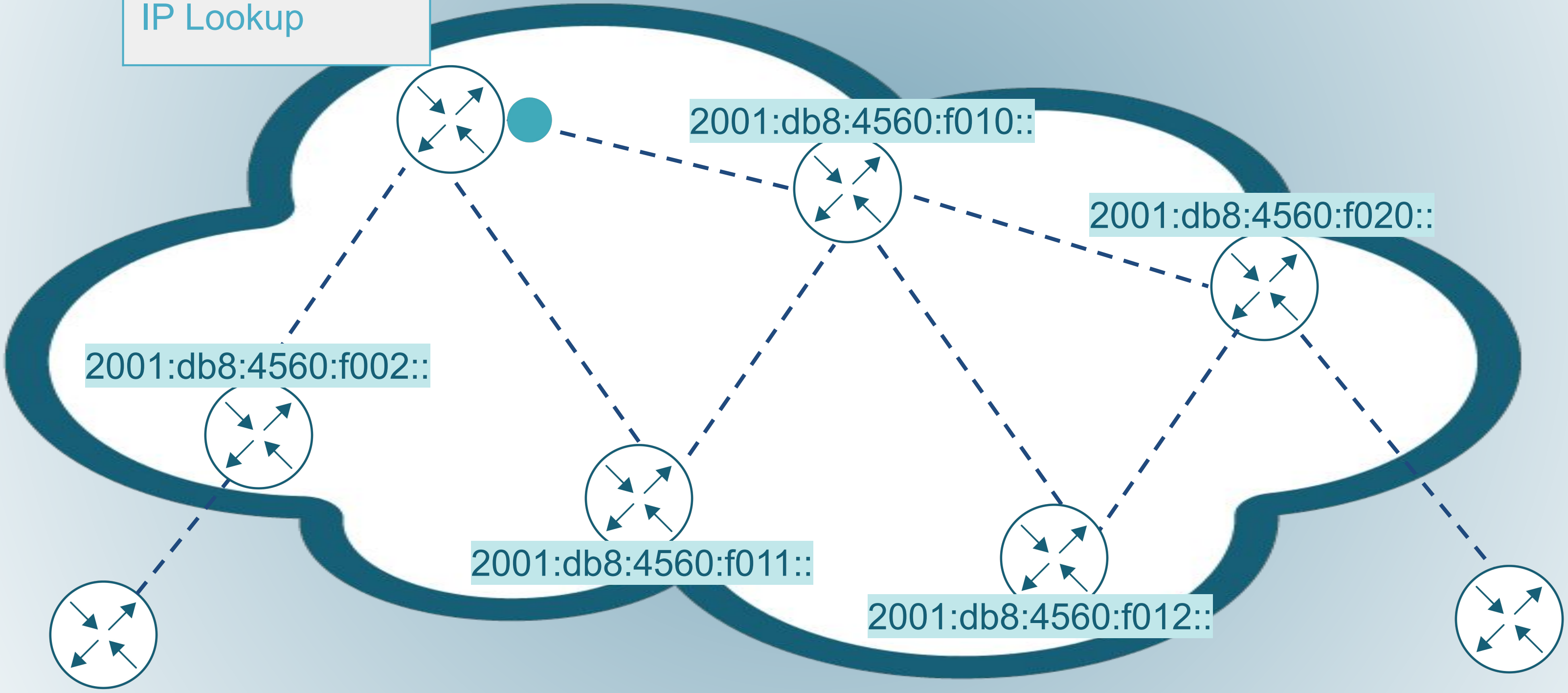
Segment Routing (SRv6)

Locator	Instruction
2001:db8:4560:f010::	::100
2001:db8:4560:f012::	::200
2001:db8:4560:f010::	::100



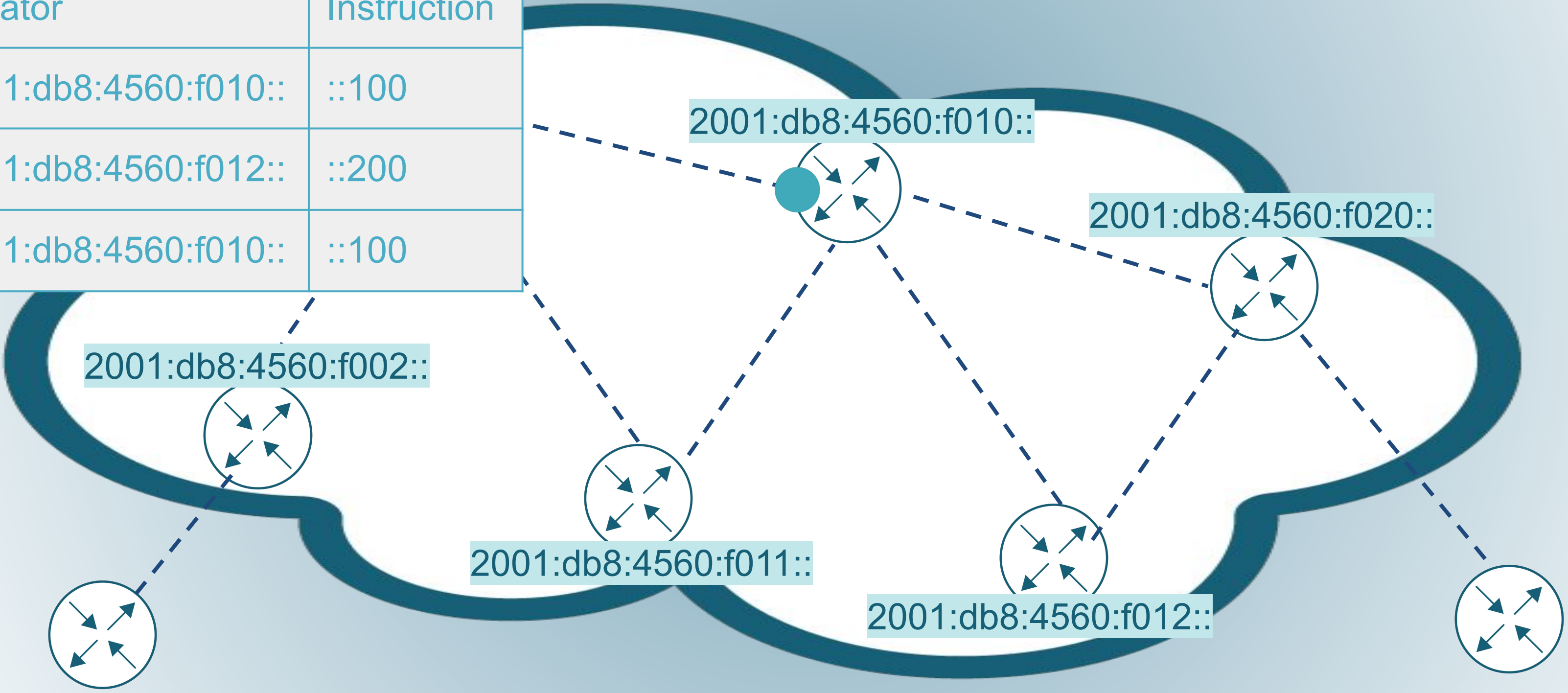
Segment Routing (SRv6)

IP Lookup



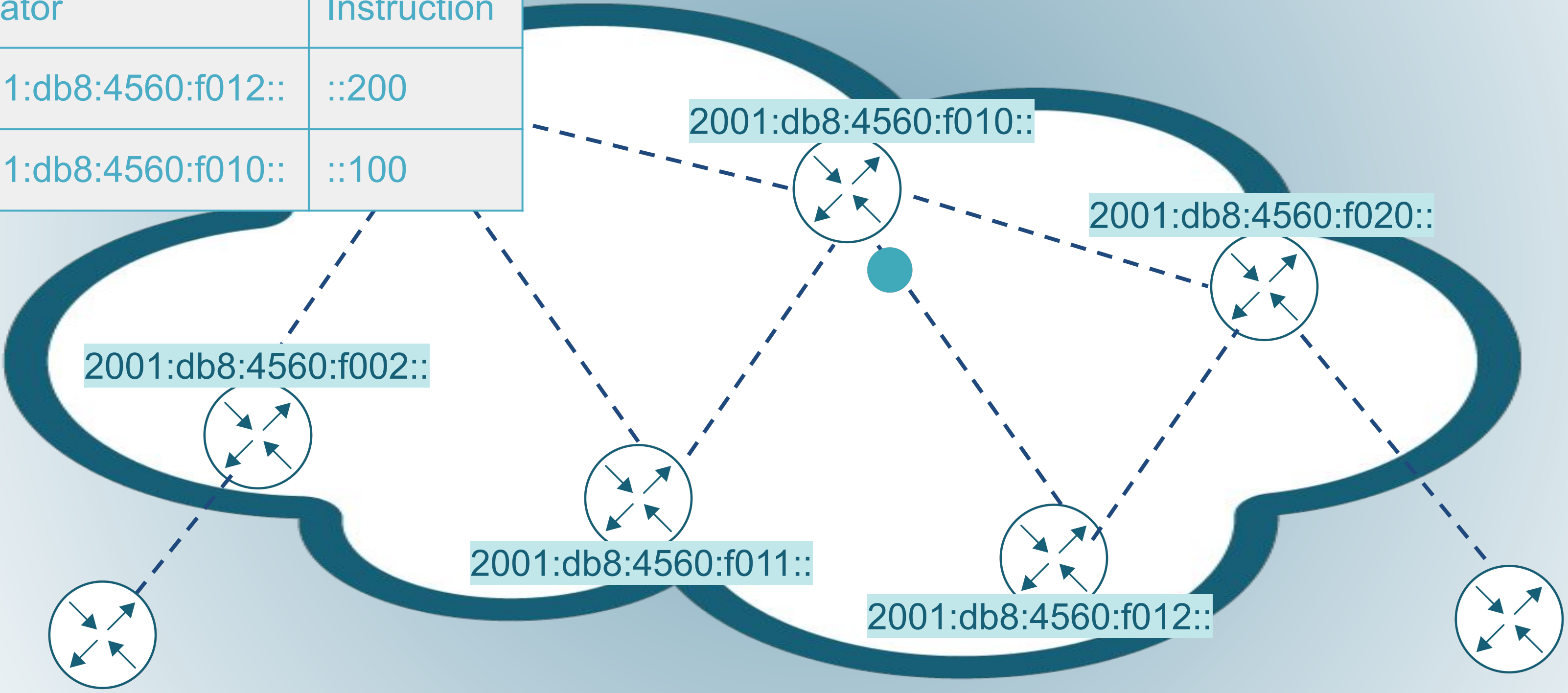
Segment Routing (SRv6)

Locator	Instruction
2001:db8:4560:f010::	::100
2001:db8:4560:f012::	::200
2001:db8:4560:f010::	::100



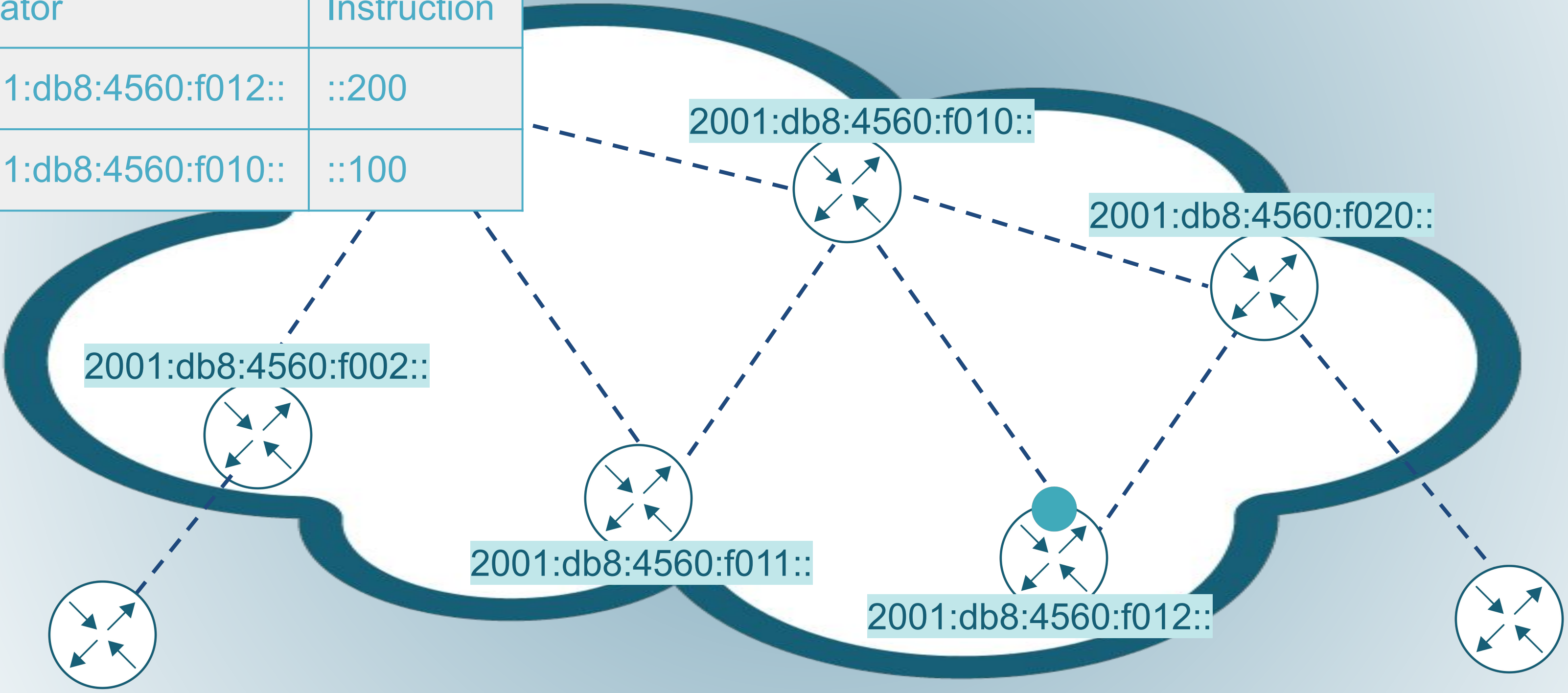
Segment Routing (SRv6)

Locator	Instruction
2001:db8:4560:f012::	::200
2001:db8:4560:f010::	::100



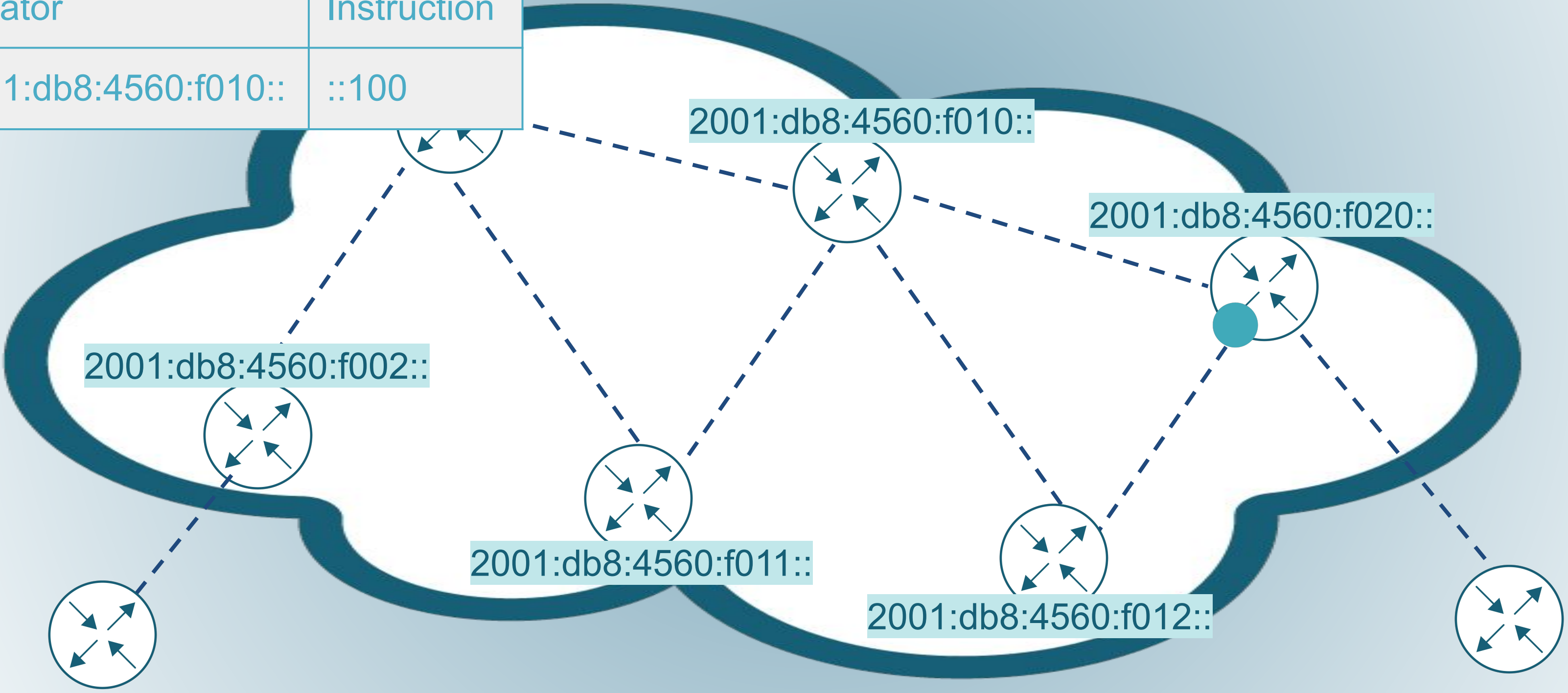
Segment Routing (SRv6)

Locator	Instruction
2001:db8:4560:f012::	::200
2001:db8:4560:f010::	::100



Segment Routing (SRv6)

Locator	Instruction
2001:db8:4560:f010::	::100



SRv6: So What?

- No LDP, RSVP-TE, NSH; underlay and overlay are the same protocol (IP)
- TI-LFA: precalculated backup route for FRR
- Service chaining
  - NFV topology and service are in the same header
  - Chain HW and SW appliances in native IP
- No state tables for NFV or TE
- Incremental deployment
- SDN support implicit

Potential Regulatory Drivers

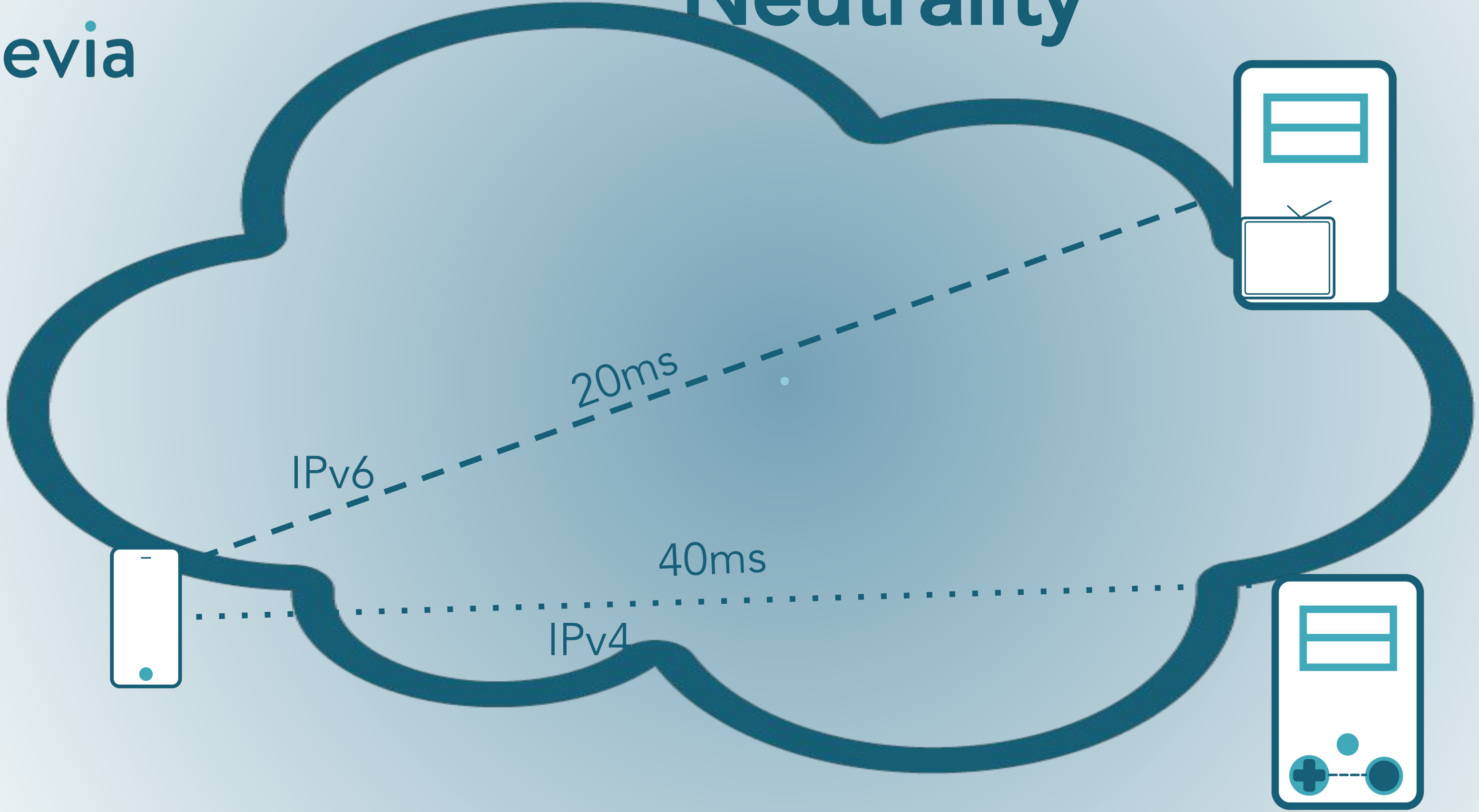
Competition

All I have to do is outlast the competition

Why is it so expensive to build a new network?

All I have to do is outlast the competition

Neutrality



Perceived Obstacles

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Obstacles

- (training, not a priority and why it maybe should be)
- "Lack of customer readiness (55%) and demand (48%) are the main challenges respondents face in relation to IPv6 deployment. A lack of skills and experience within their organisation is also making IPv6 deployment challenging. Reflecting focus group feedback, many organisations also see little economic or operational benefit in implementing IPv6, reducing the urgency to deploy until it is absolutely necessary for their organisation."
  - https://www.apnic.net/wp-content/uploads/2018/09/2018-APNIC-Member-Survey-Report.pdf
-

2018 APNIC Member Survey

Our customers are not ready for IPv6	55%
There is no demand for IPv6 from customers	48%
Lack of skills and expertise within our organisation	46%
No clear business / technical advantages or reasons to adopt IPv6	35%
Lack of applications that can run on IPv6	35%
Lack of available training	33%
My organisation's legacy systems do not support IPv6	22%
Our upstream providers do not support IPv6	17%
Cost of IPv6 deployment is too high	16%
The risks of deploying IPv6 are too high	13%

Security

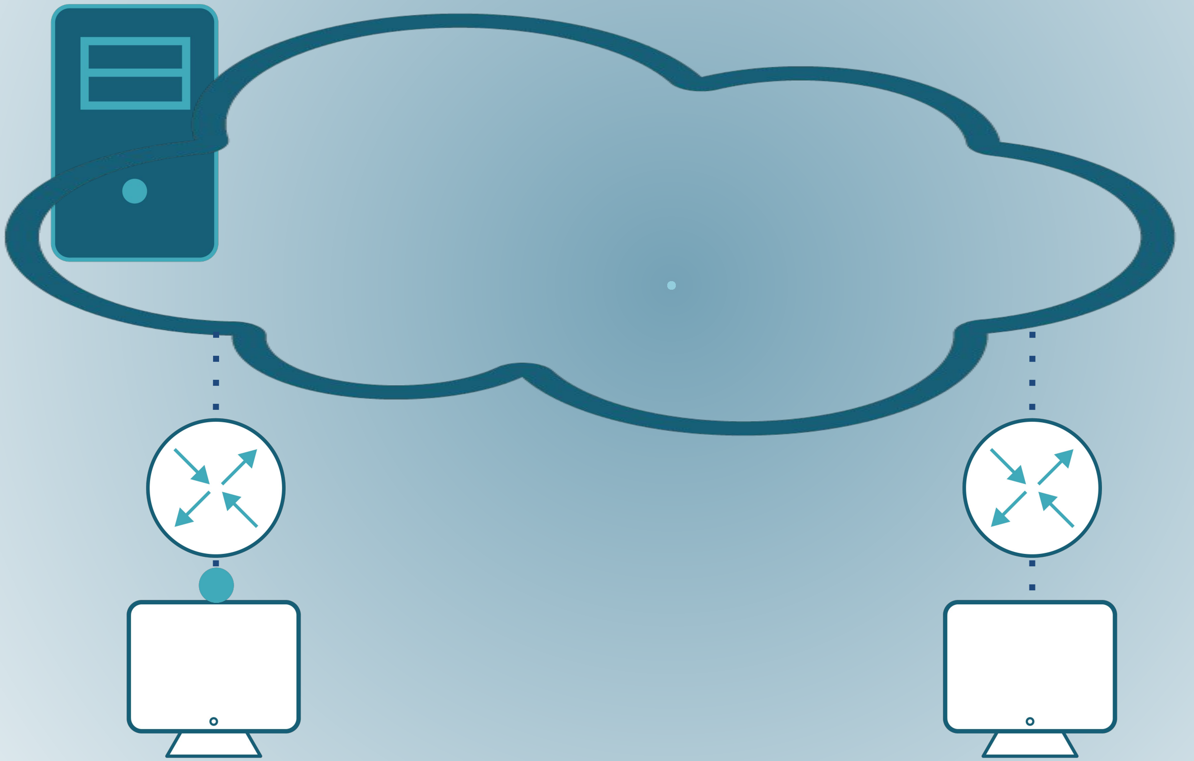
Popular Misconceptions

1. We're safe because we haven't turned on IPv6 yet.
2. NAT keeps us secure.
3. At least with all that address space, host scanning is a thing of the past.
4. IPv6 is more secure because it requires IPSec.

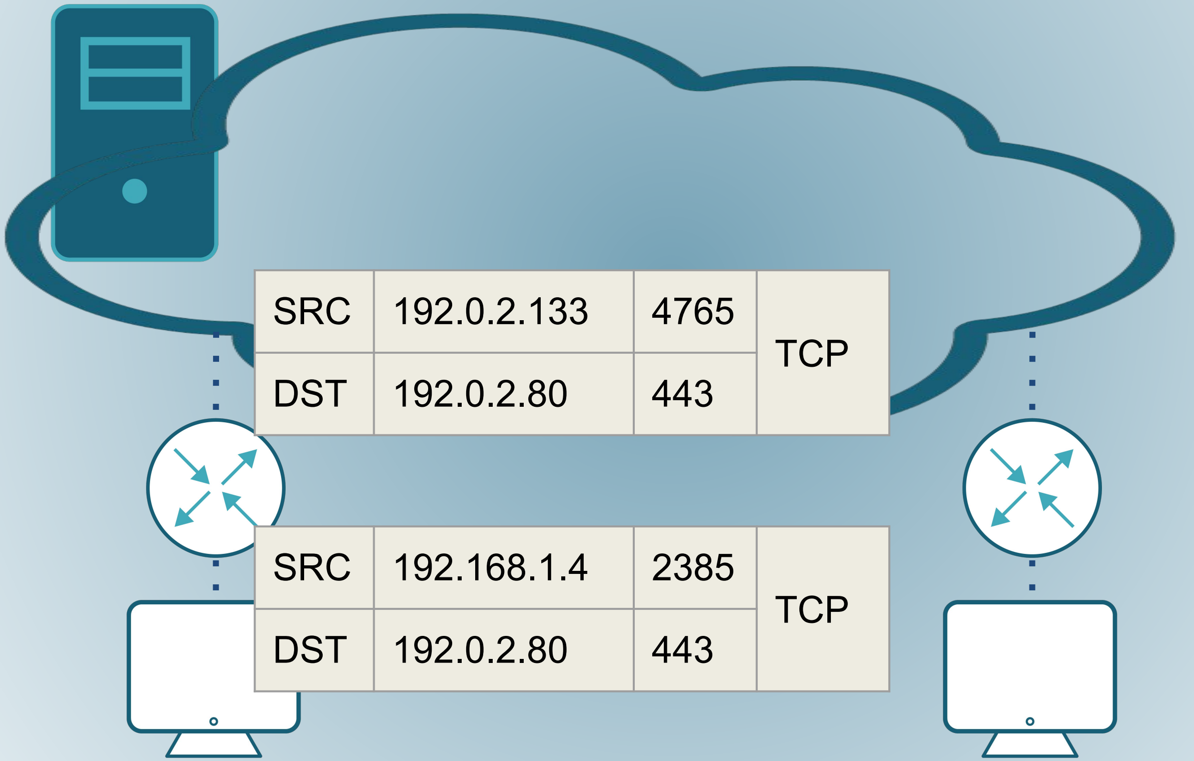
IPv6: On by Default

- Unless you have pushed policies to hosts to disable IPv6, LLA is already turned on
- Some firewalls have IPv6 open by default
- Some IDS/IPS ignore unrecognized traffic
- Many IPv6 transition technologies are tunnels

NAT is not a Firewall



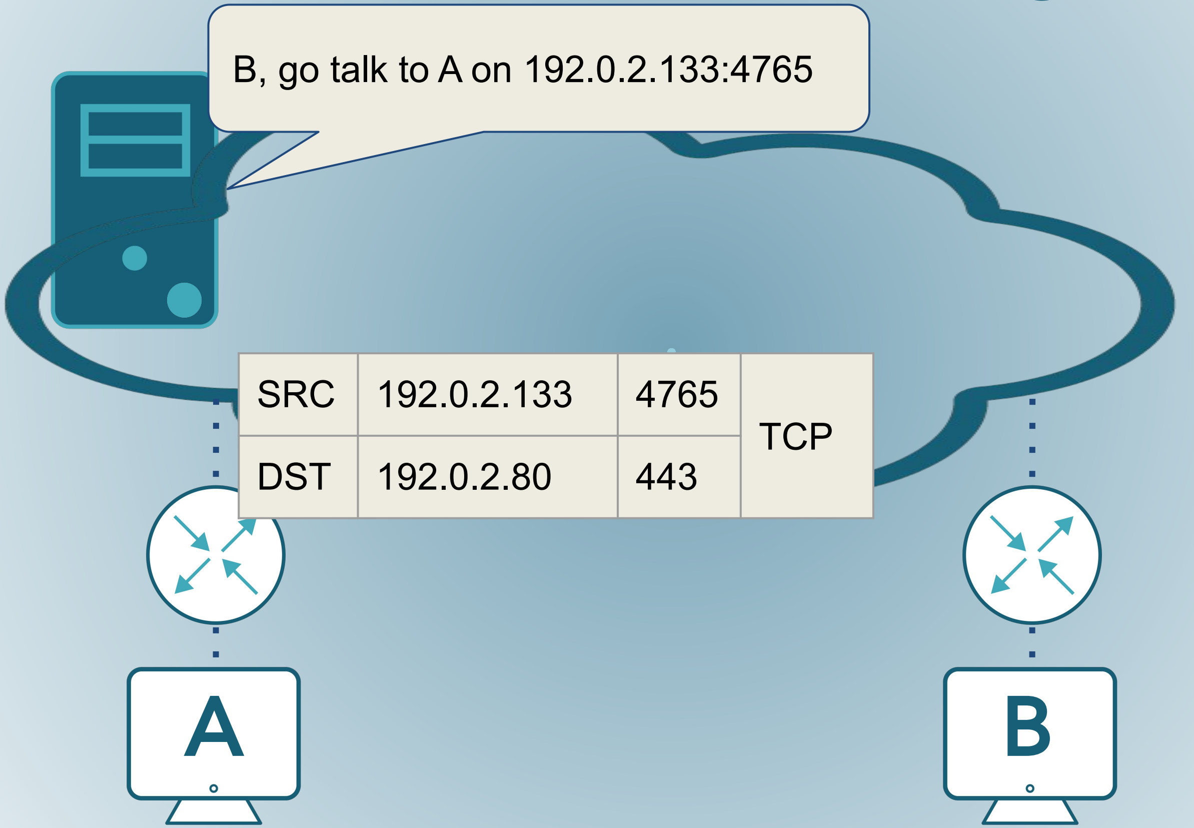
Basic NAPT Translation



SRC	192.0.2.133	4765	TCP
DST	192.0.2.80	443	

SRC	192.168.1.4	2385	TCP
DST	192.0.2.80	443	

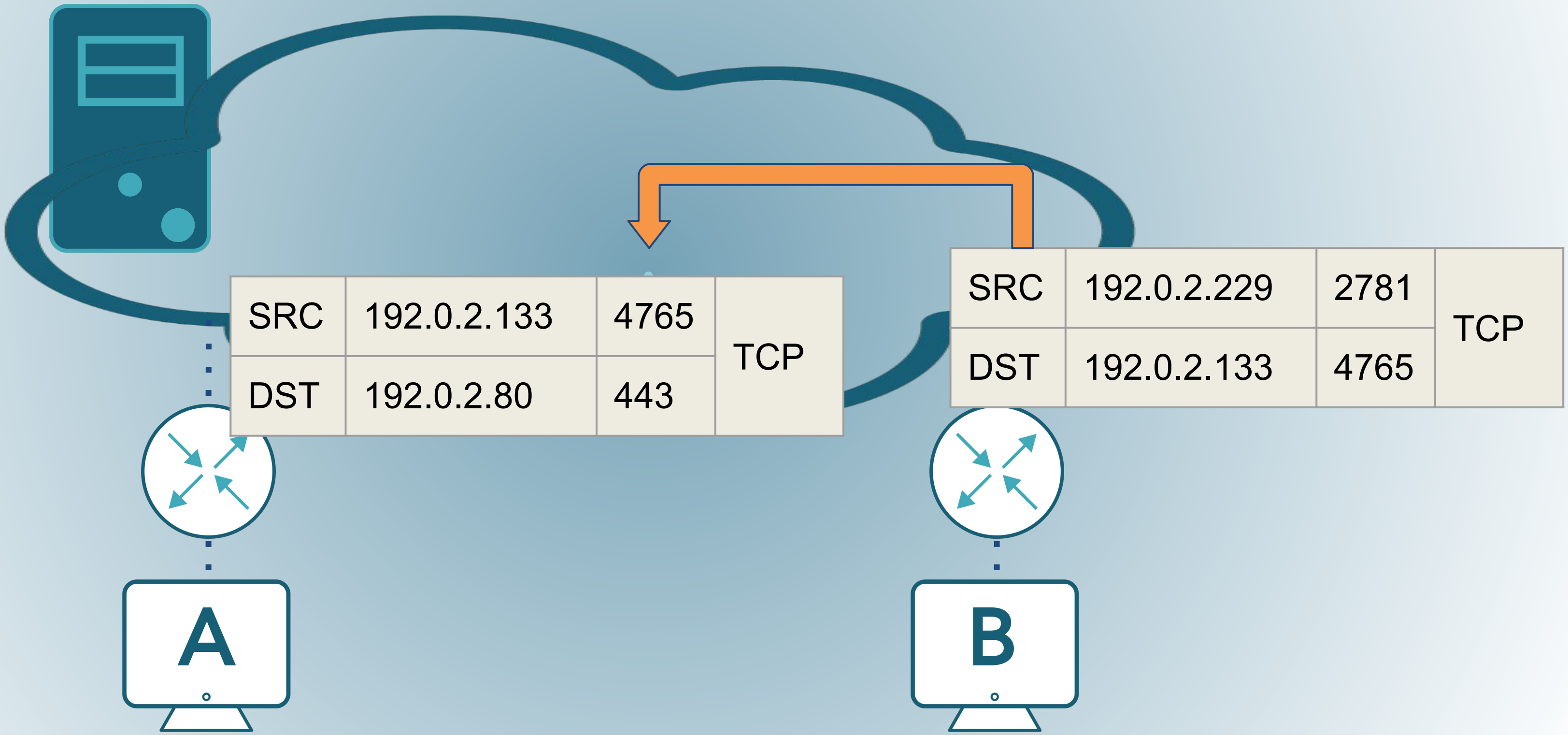
What about p2p or gaming?



B, go talk to A on 192.0.2.133:4765

SRC	192.0.2.133	4765	TCP
DST	192.0.2.80	443	

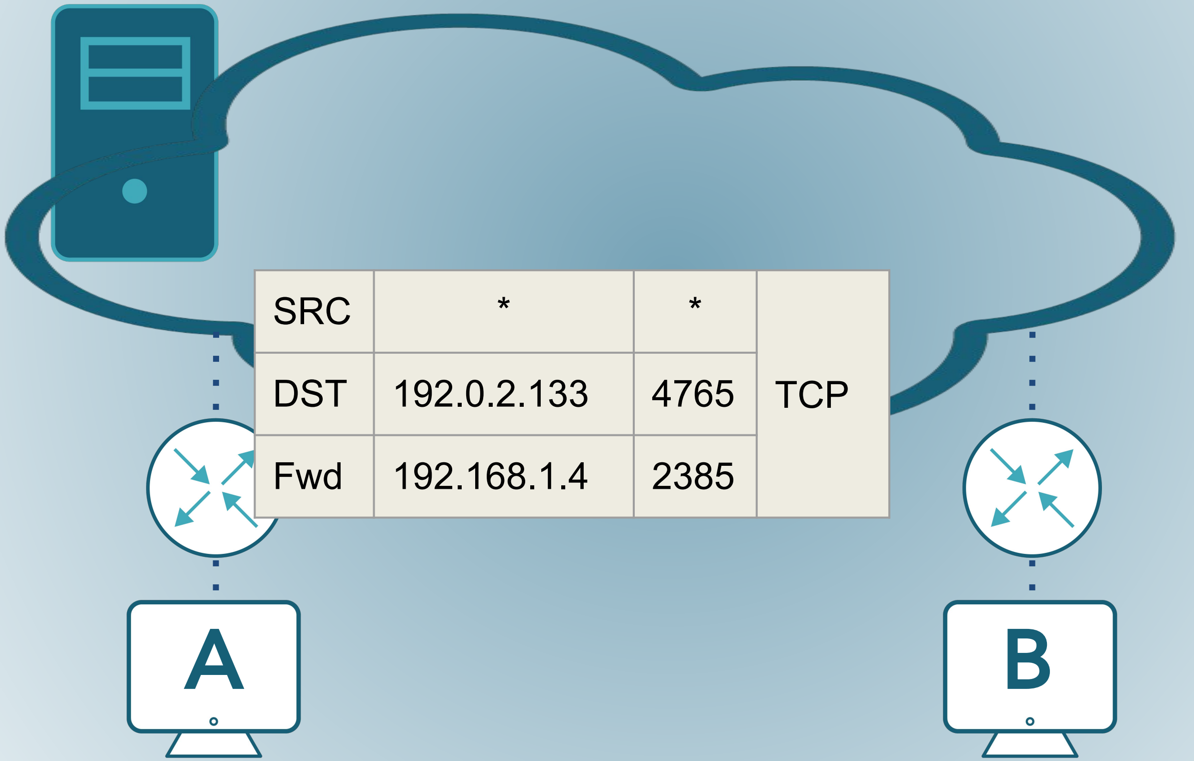
If NAT was FW, packet drops



SRC	192.0.2.133	4765	TCP
DST	192.0.2.80	443	

SRC	192.0.2.229	2781	TCP
DST	192.0.2.133	4765	

Full cone NAT forwards *



SRC	*	*	TCP
DST	192.0.2.133	4765	
Fwd	192.168.1.4	2385	

Host Scanning

- 2^{64} = 18,446,744,073,709,551,616 addresses
- But within 2001:db8:f001:1::/64 likely host addresses include
  - ::1
  - ::2
  - ::80
  - ::1:1
  - ::beef
  - ::<192.0.2.x>

Host Scanning

- 2001:db8:f001:1::/64 where host bits are EUI-64
  - ::<OUI>ff:feXX:XXXX
  - Pick OUIs from popular NICs and scan 16M addresses
- Lookup or xfer DNS and rDNS
  - Q 1.0.8.0.0.8.b.d.0.1.0.0.2.ip6.arpa.
    - NODATA means the zone exists, so scan for hosts
    - NXDOMAIN means no zone, probably no hosts
- Scan BitTorrent sites or other servers for address logs
-

Host Scanning Mitigations

- FW/IPS blocking ICMPv6 that looks like scanning
- FW or host configured to drop ICMPv6 Echo Request
  - But not ICMPv6 PTB!
    - Policing is possible to prevent DoS of large packet floods,
    - But too-big packets can only arrive on routers with links of different MTUs
- Ignore what I said earlier about mnemonic addresses
- Privacy extensions: randomly change address

IPSec will save us!

Rfc2401 “Security Architecture for the Internet Protocol” says

```
This section defines Security Association management requirements for
   all IPv6 implementations and for those IPv4 implementations that
   implement AH, ESP, or both.
```

So it’s mandatory!

LOCAL RISKS

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NDP

Vulnerability

- Unauthenticated ND, RA, etc. (same as ARP)
  - Hello, I’m 2001:db8::1
    - No, I’m 2001:db8::1
  - Hello, I’m a router for 2001:db8::/32
- Cache table exhaustion

SLAAC vs DHCPv6

- Some admins like DHCP because it logs who has what address
  - Except it doesn't prevent manual configuration
- Mitigations for rogue attachments
  - Log Neighbor Discovery tables
    - Syslog, SNMP, Netconf
  - 802.1x

Smurf

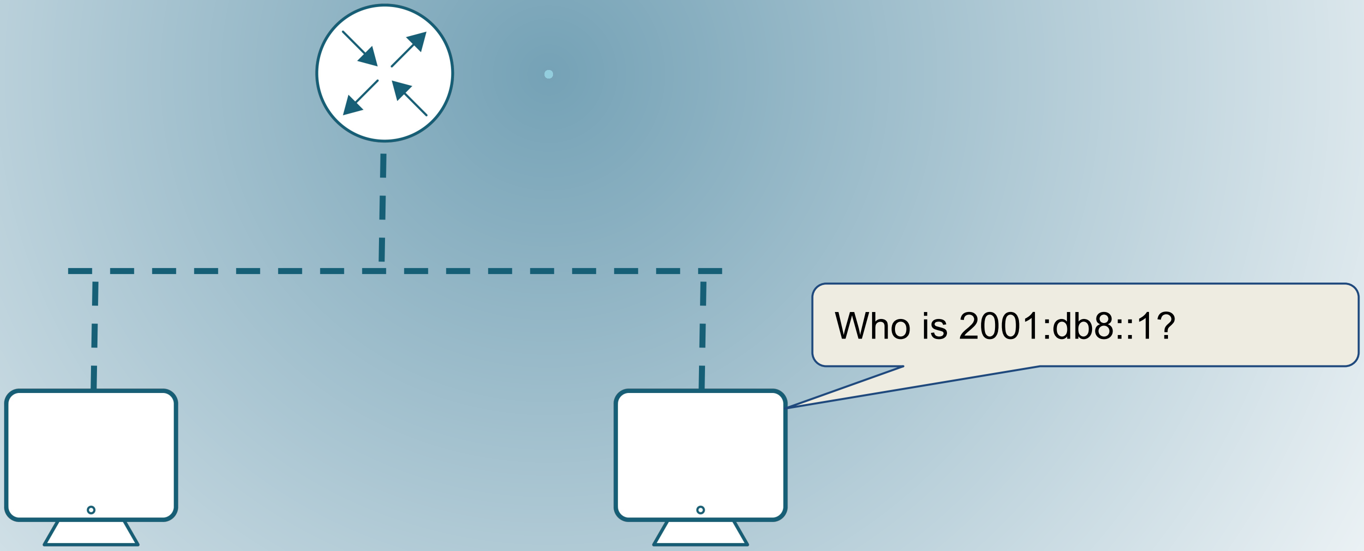
Send packets with spoofed source address (the victim) to a multicast address, for many responses to DOS the victim

Address	Description	Scope
FF01::1	All Nodes Address	Node-Local
FF01::2	All Routers Address	Node-Local
FF02:0:0:0:0:0:0:1	All Nodes Address	Link-Local
FF02:0:0:0:0:0:0:2	All Routers Address	Link-Local
FF02:0:0:0:0:0:0:5	OSPFIGP	Link-Local
FF02:0:0:0:0:0:0:6	OSPFIGP Designated Routers	Link-Local
FF02:0:0:0:0:0:0:C	SSDP	Link-Local
FF02:0:0:0:0:0:0:12	VRRP	Link-Local
FF02:0:0:0:0:0:0:FB	mDNSv6	Link-Local
FF02:0:0:0:0:0:1:2	All_DHCP_Relay_Agents_and_Servers	Link-Local

And many more!

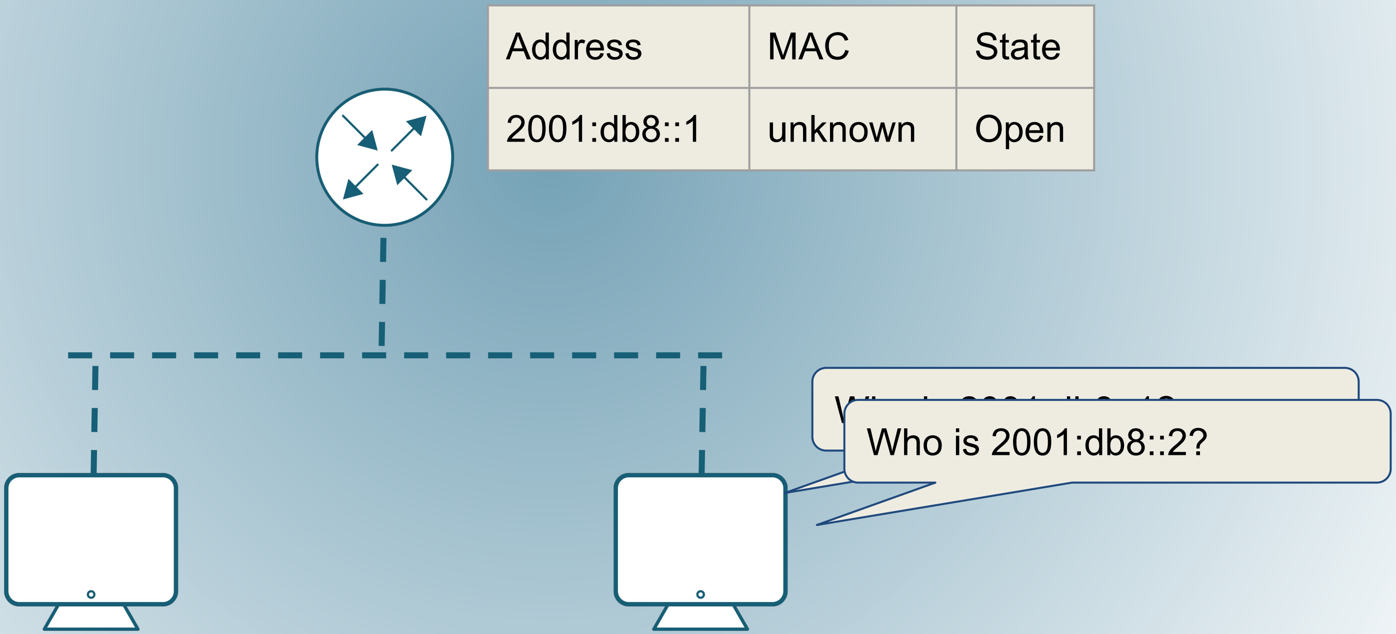
https://www.iana.org/assignments/ipv6-multicast-addresses/ipv6-multicast-addresses.xhtml

Neighbor Table Exhaustion



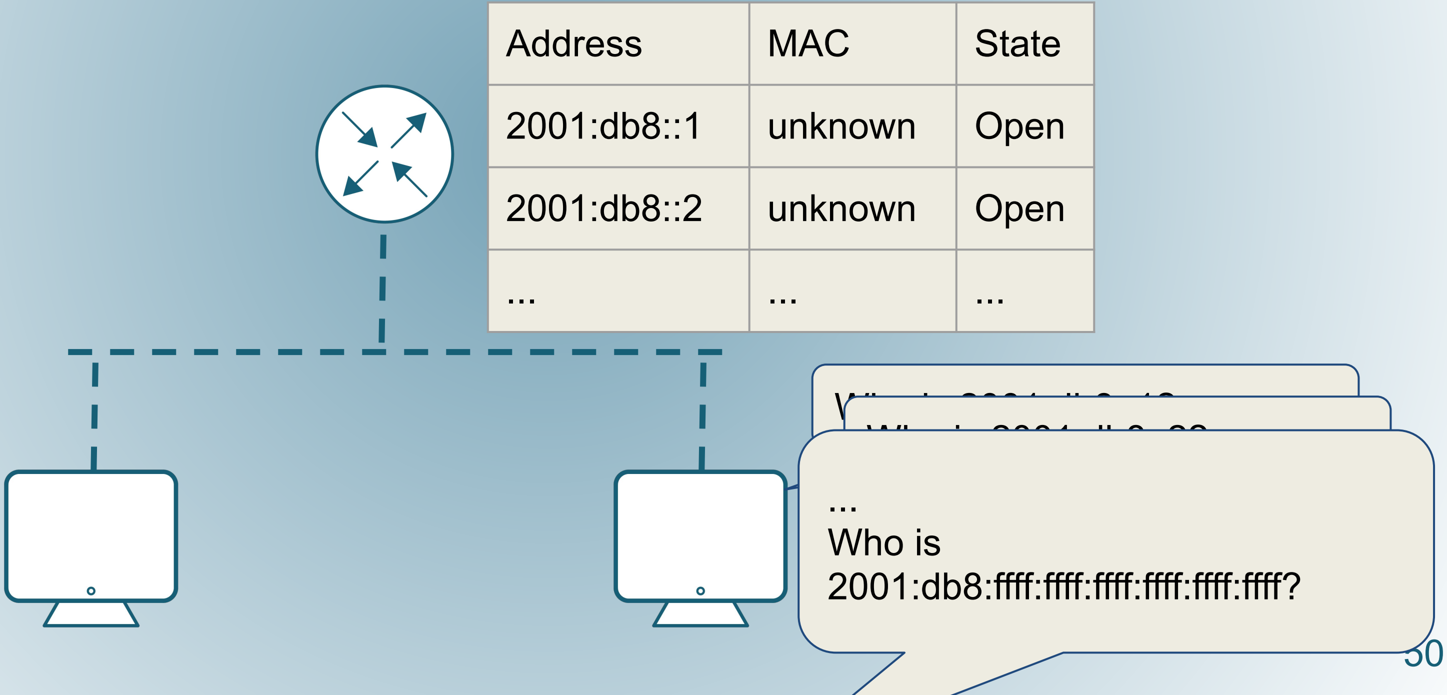
Who is 2001:db8::1?

Neighbor Table Exhaustion



Address	MAC	State
2001:db8::1	unknown	Open

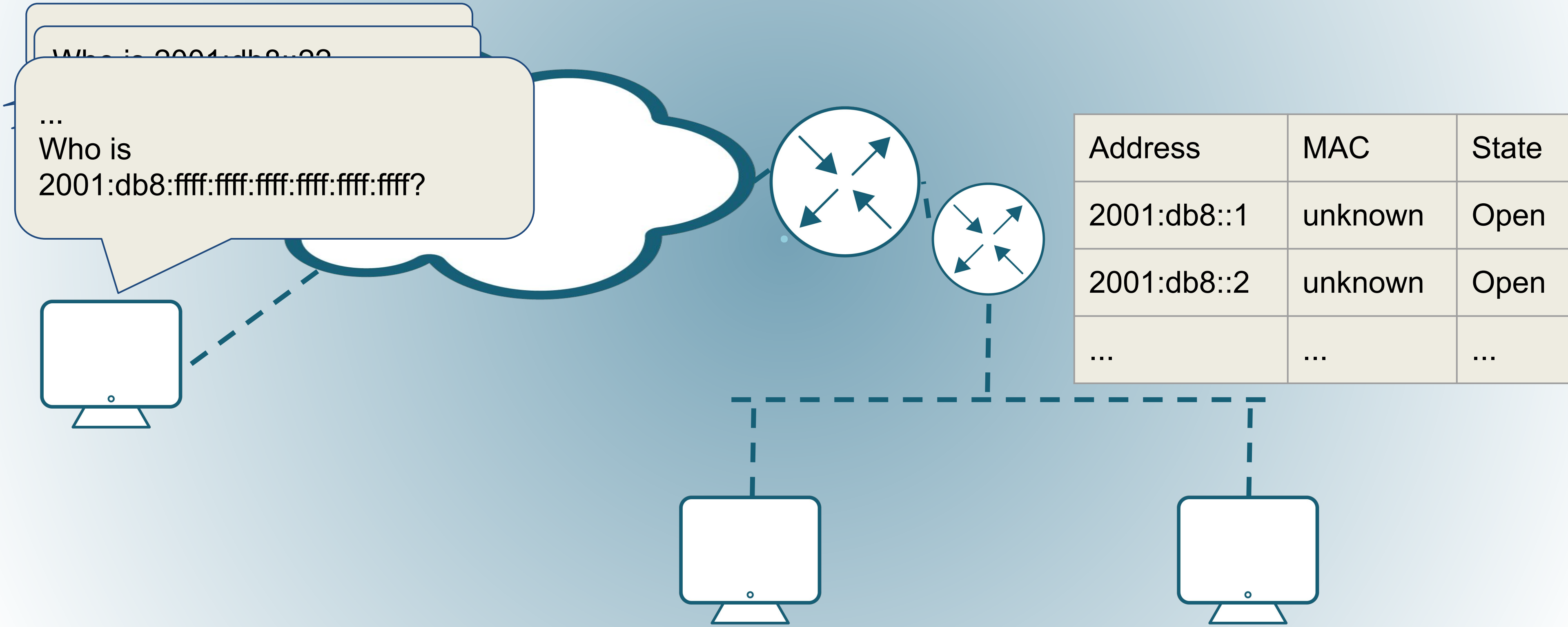
Neighbor Table Exhaustion



Address	MAC	State
2001:db8::1	unknown	Open
2001:db8::2	unknown	Open
...	...	...

...
Who is
2001:db8:ffff:ffff:ffff:ffff:ffff:ffff?

Neighbor Table Exhaustion

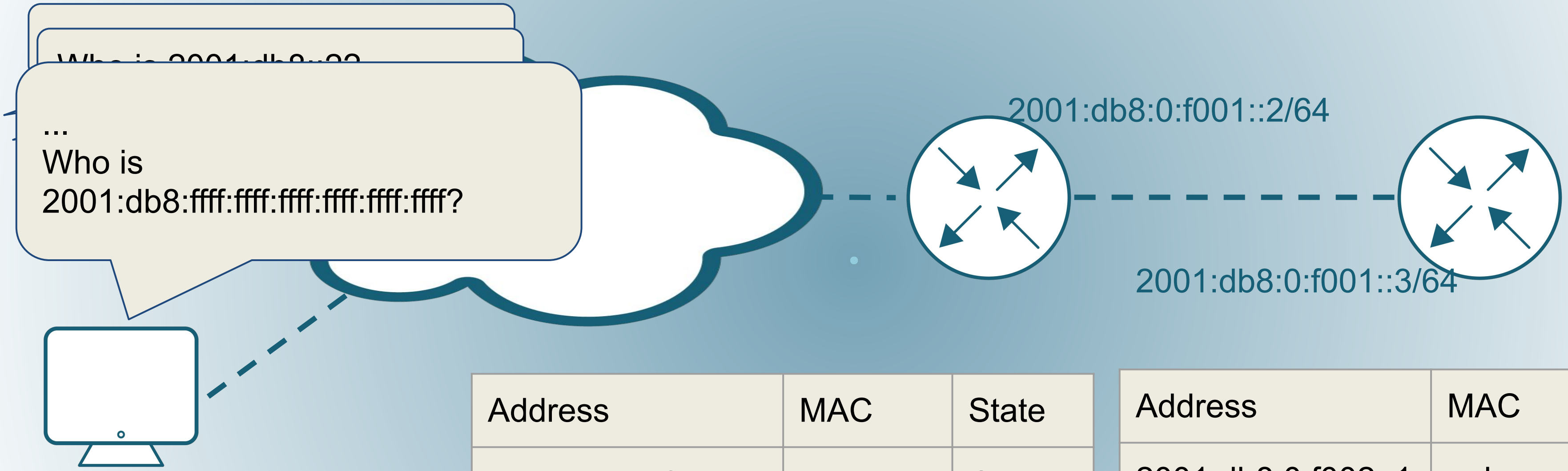


Who is 2001:db8::2?

...
Who is
2001:db8:ffff:ffff:ffff:ffff:ffff:ffff?

Address	MAC	State
2001:db8::1	unknown	Open
2001:db8::2	unknown	Open
...	...	...

Ping Pong Attack



Who is 2001:db8::2?

...
Who is
2001:db8:ffff:ffff:ffff:ffff:ffff:ffff?

Address	MAC	State
2001:db8:0:f002::1	unknown	Open
2001:db8:0:f002::4	unknown	Open
...	...	...

Address	MAC	State
2001:db8:0:f002::1	unknown	Open
2001:db8:0:f002::4	unknown	Open
...	...	...

NDT Mitigations

- /127 netmask
- ACL on unused space
- NDP Queue rate limit
  - If device has different queues for confirming existing entries and resolving new queries, tighten new query queue
- Rate limit ICMPv6
- and several mechanisms to log bad NDP. . .

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SeND

- Secure path to CA
  - Send request for CA
  - Each node on the path sends its cert
  - CA confirms each cert
- Use key pair to generate CGA
  - CryptoGraphically Assigned host bits
- Send RS; Router replies with signed RA
- Uses SHA-1 and PKIX; not highly secure
  - Because longer keys would exceed MTU, requiring frag

RA-Guard

- L2 switch can prevent malicious/spurious RAs
- Multiple possible policies
  - Block RAs from specific MAC or port
  - Allow RAs only from specific MAC or port
  - Allow RAs that comply with (e.g., SeND) policy
  - Or use prefix list, prefix range, router priority
- Switch can become RA proxy
- Off -> Learning -> Blocking -> Forwarding

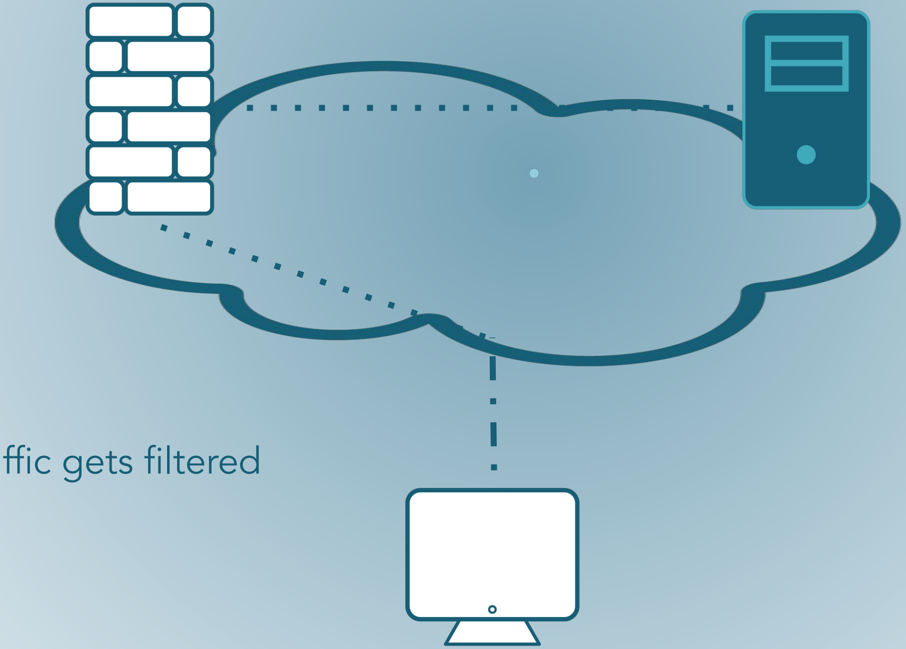
SAVI

- Source Address Verification Improvements against spoofing
- FCFS SAVI: first user of address (within prefix list or RA) is authorized user
- SeND SAVI: drop packets where SRC not certified
- SAVI with DHCP: snoop DHCP, drop packets from IP addresses not assigned by DHCP
- SAVI-MIX: if two SAVIs conflict, resolve in order

Cisco, in their IPv6-only enterprise network

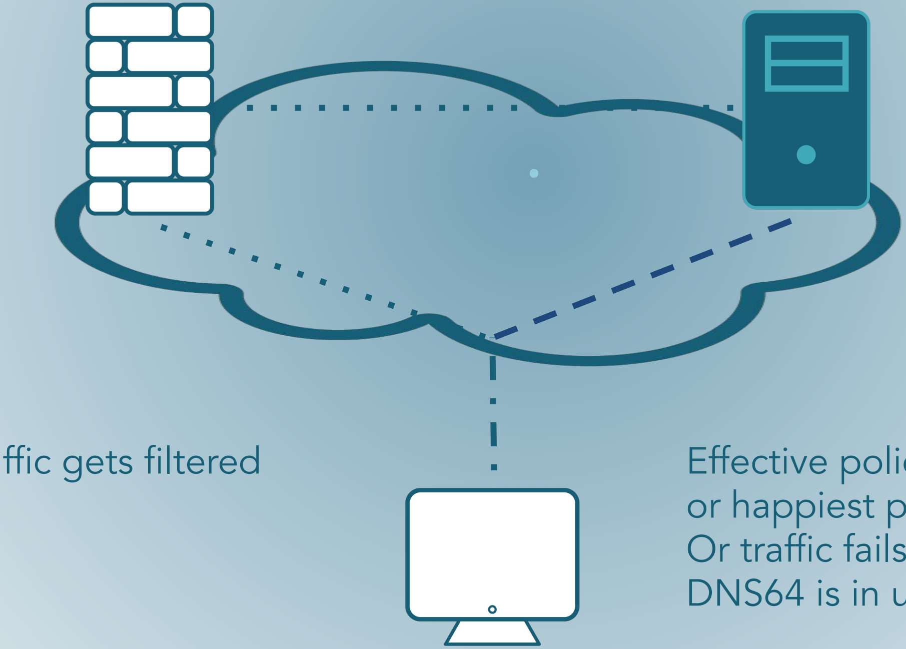
- First Hop Security
  - IPv6 Snooping (Address Gleaning, Device Tracking)
  - ND Inspection
  - DHCPv6 Guard
  - RA Guard
  - Source Guard
- Data center: Cloud security

VPN



Intended policy: traffic gets filtered through VPN

VPN



Intended policy: traffic gets filtered through VPN

Effective policy: traffic takes shortest or happiest path
Or traffic fails to DS server, or if DNS64 is in use

Fragmentation

- Remember that only sender can fragment
- SeND RA might be too big and require frag
  - Local sender could send fragments that collide with SeND
- RA with many PIOs might require frag
  - Send multiple RAs instead
- Good place to troubleshoot if RAs are failing silently

FIREWALL SPECIFICS

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Extension Headers

- Extension Headers
  - HBH
  - DO
  - Routing
  - Fragment
  - AH, ESP
  - Others. . . see IANA registry
- L4 or higher inspection?
  - Parse all headers to find pointer to the Upper-Layer Header

ICMPv6

- Link local multicast and address discovery
- ICMPv6 message types
  - Destination Unreachable
  - PTB
  - Time Exceeded
  - Parameter Problem
  - Echo Request
  - Echo Reply

Spam

- 22/50 top sites have IPv6 MX records
  - 20 of them use Google for mail.
  - LinkedIn, WikiMedia.
- IP reputation tools are terrible at IPv6
  - Block /64? /60? /56? /48?

IPv6-Specific Security Tools

- THC
- IPv6-Toolkit
- FT6 Firewall Tester
- Many existing tools

Running a dual-stack network doubles the attack exposure as a malevolent person has now two attack vectors: IPv4 and IPv6.

--RFC7381 “Enterprise IPv6 Deployment Guidelines”

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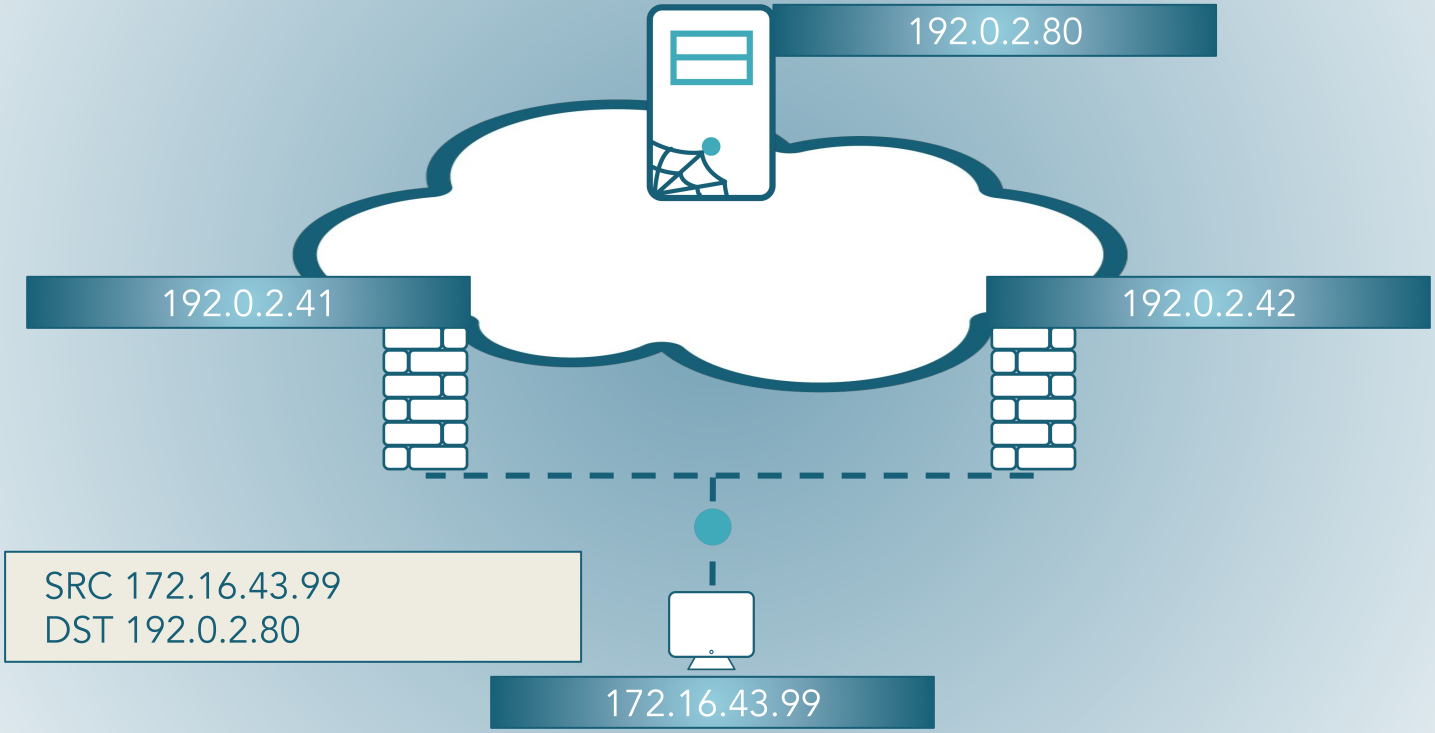
The Multihoming Problem

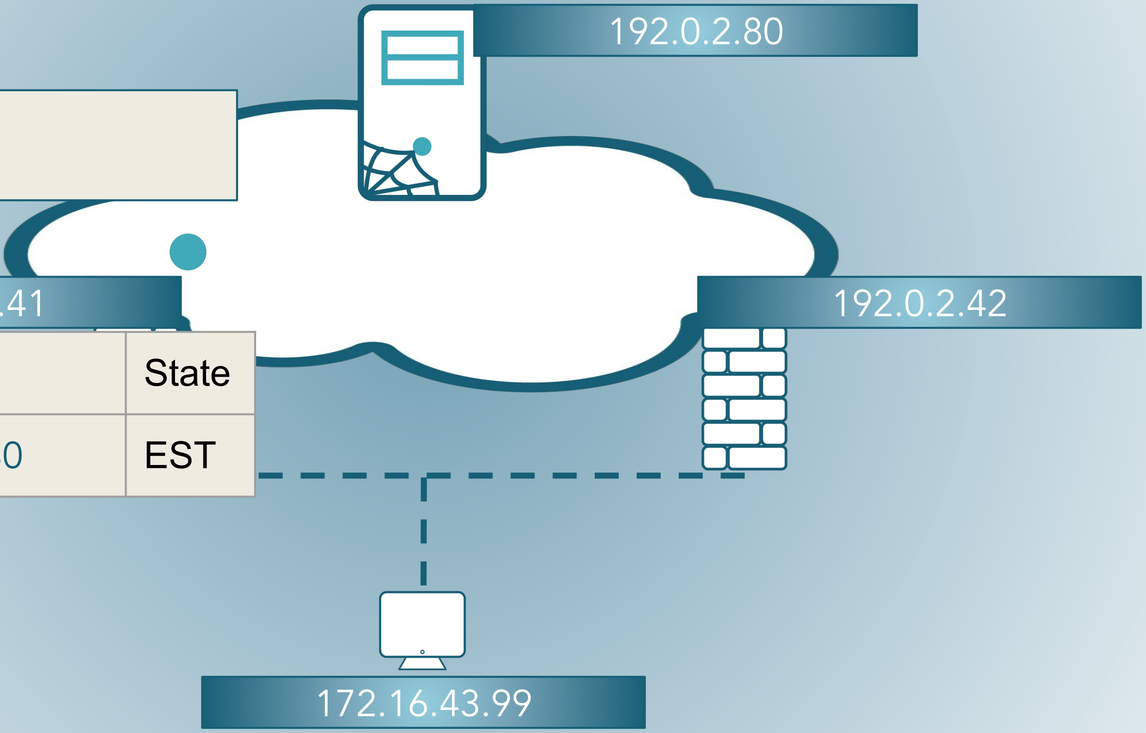
Multihoming Status Quo



SRC 172.16.43.99
DST 192.0.2.80

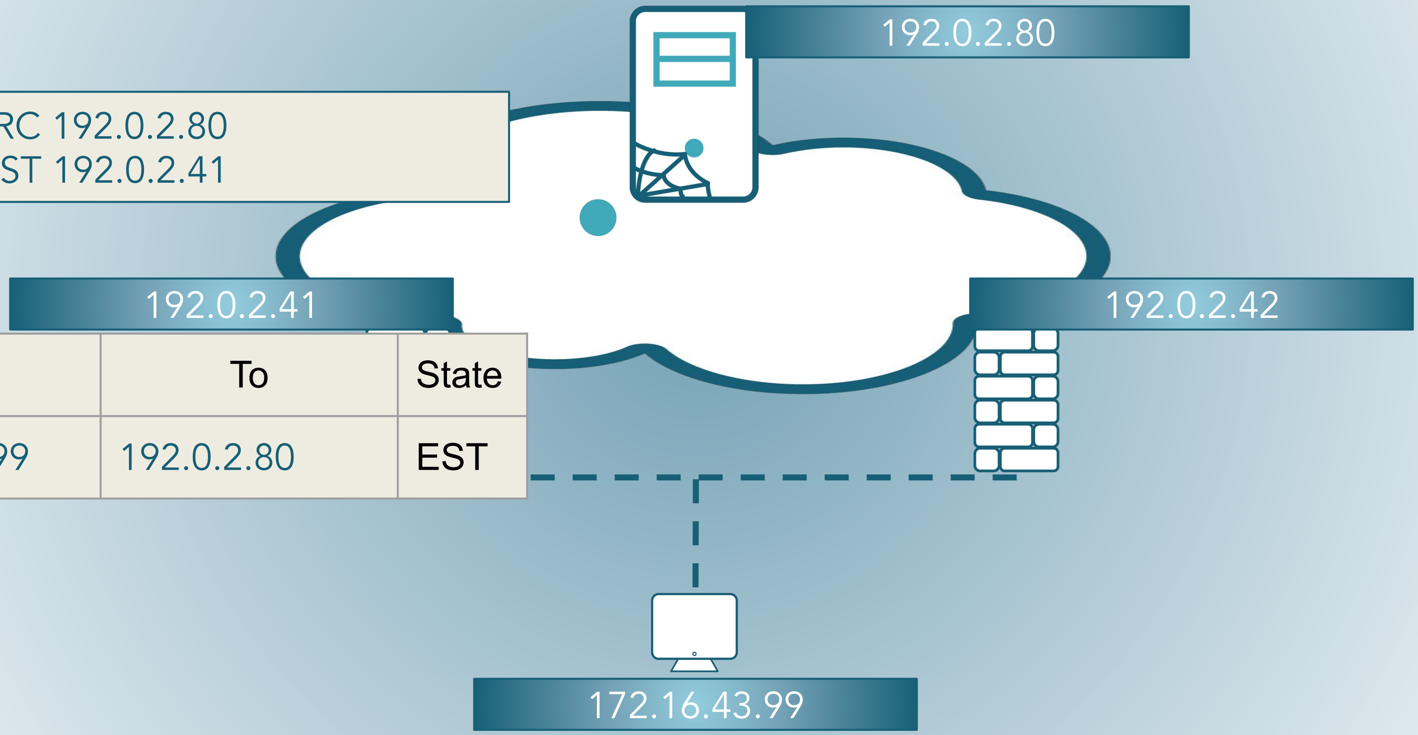
Multihoming Status Quo

SRC 192.0.2.41
DST 192.0.2.80



From	To	State
172.16.43.99	192.0.2.80	EST

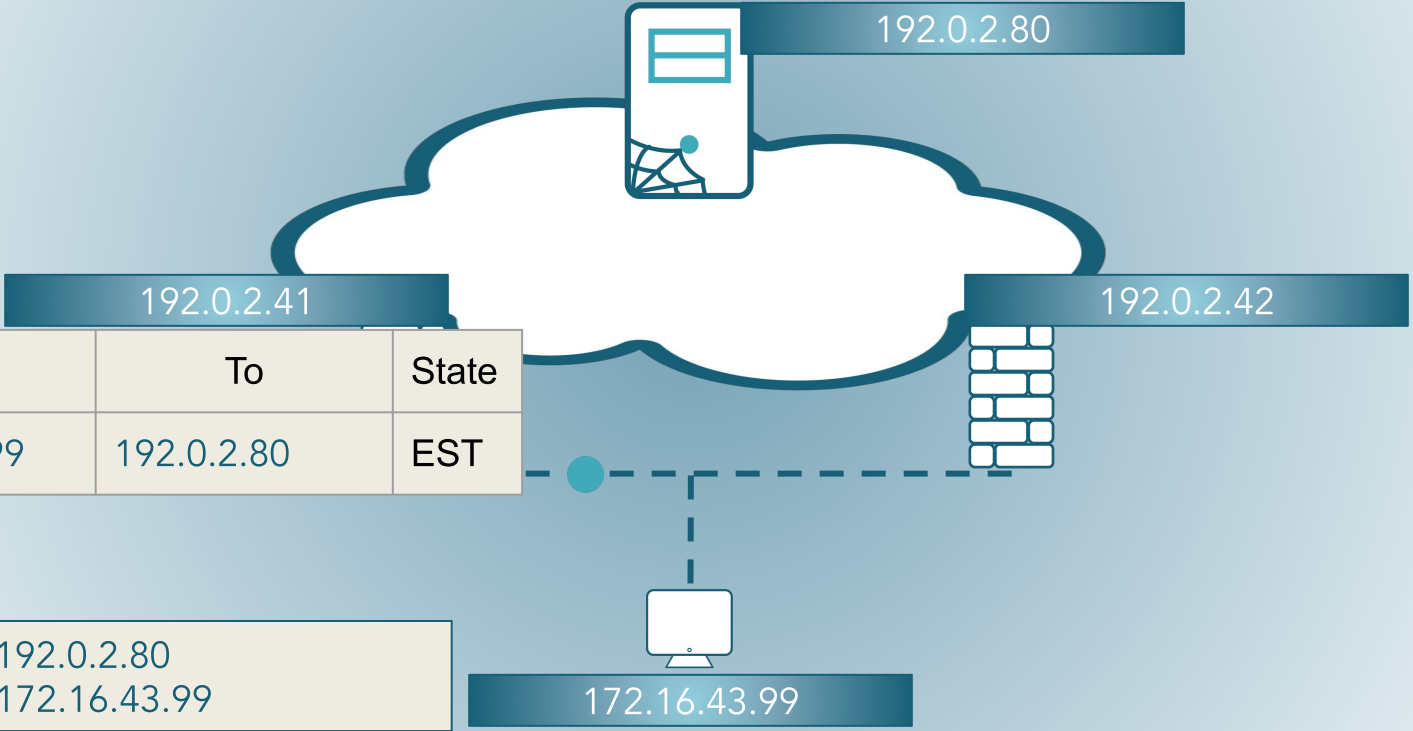
Multihoming Status Quo



SRC 192.0.2.80
DST 192.0.2.41

From	To	State
172.16.43.99	192.0.2.80	EST

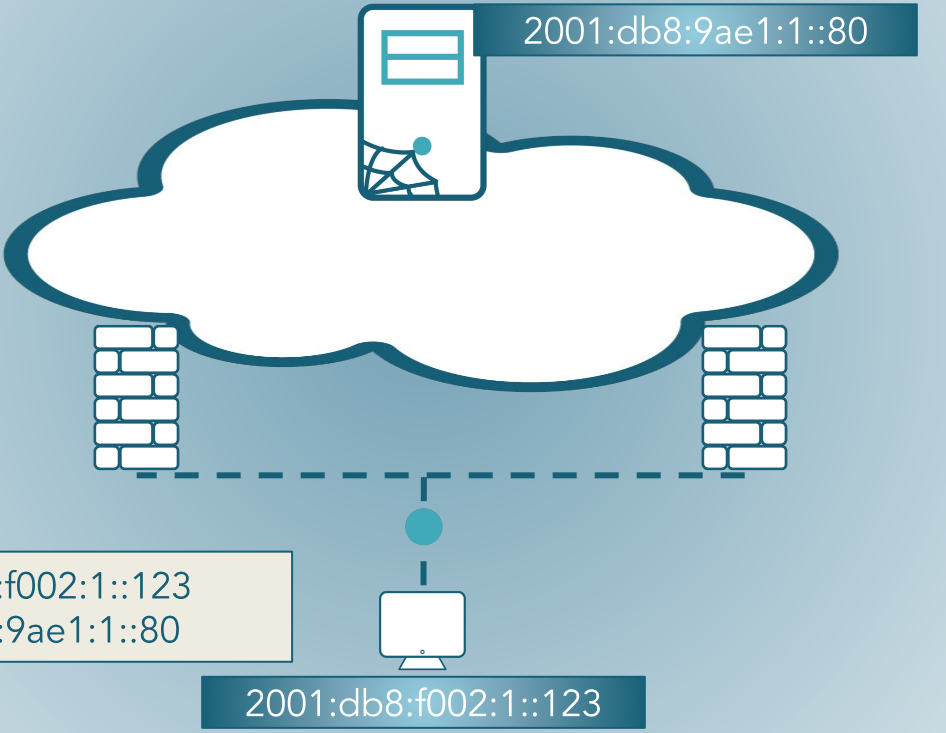
Multihoming Status Quo



From	To	State
172.16.43.99	192.0.2.80	EST

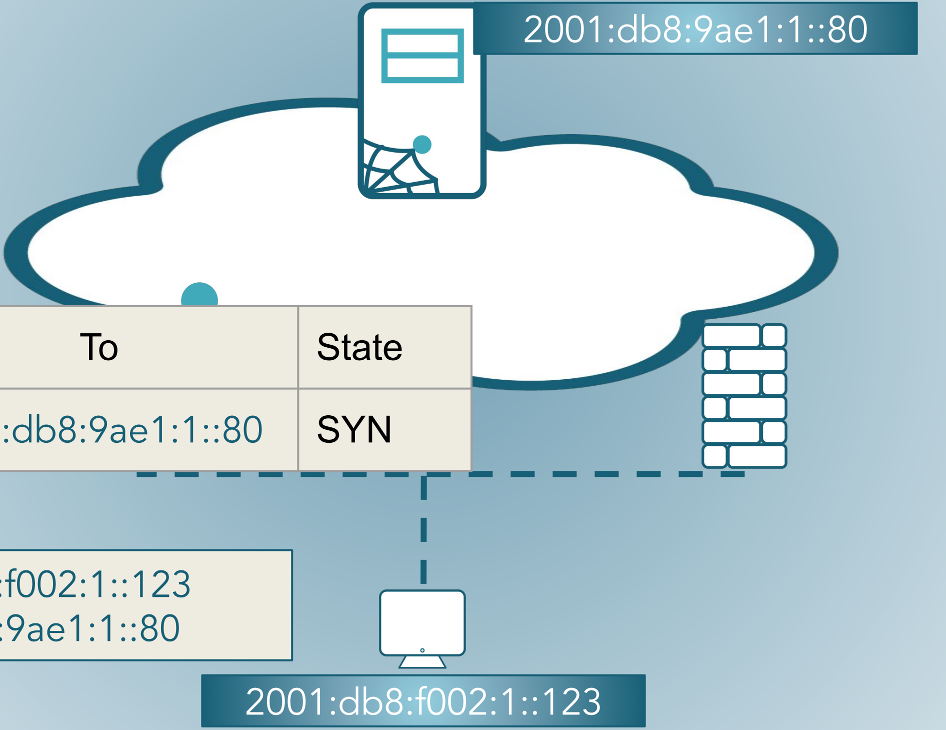
SRC 192.0.2.80
DST 172.16.43.99

The Multihoming Problem



SRC 2001:db8:f002:1::123
DST 2001:db8:9ae1:1::80

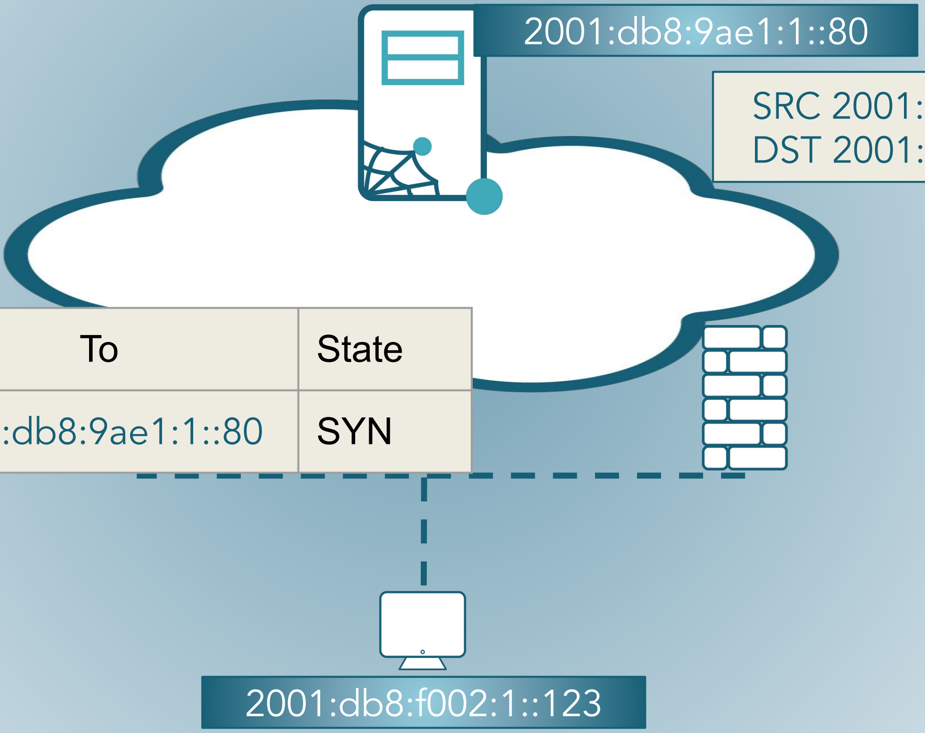
The Multihoming Problem



From	To	State
2001:db8:f002:1::123	2001:db8:9ae1:1::80	SYN

SRC 2001:db8:f002:1::123
DST 2001:db8:9ae1:1::80

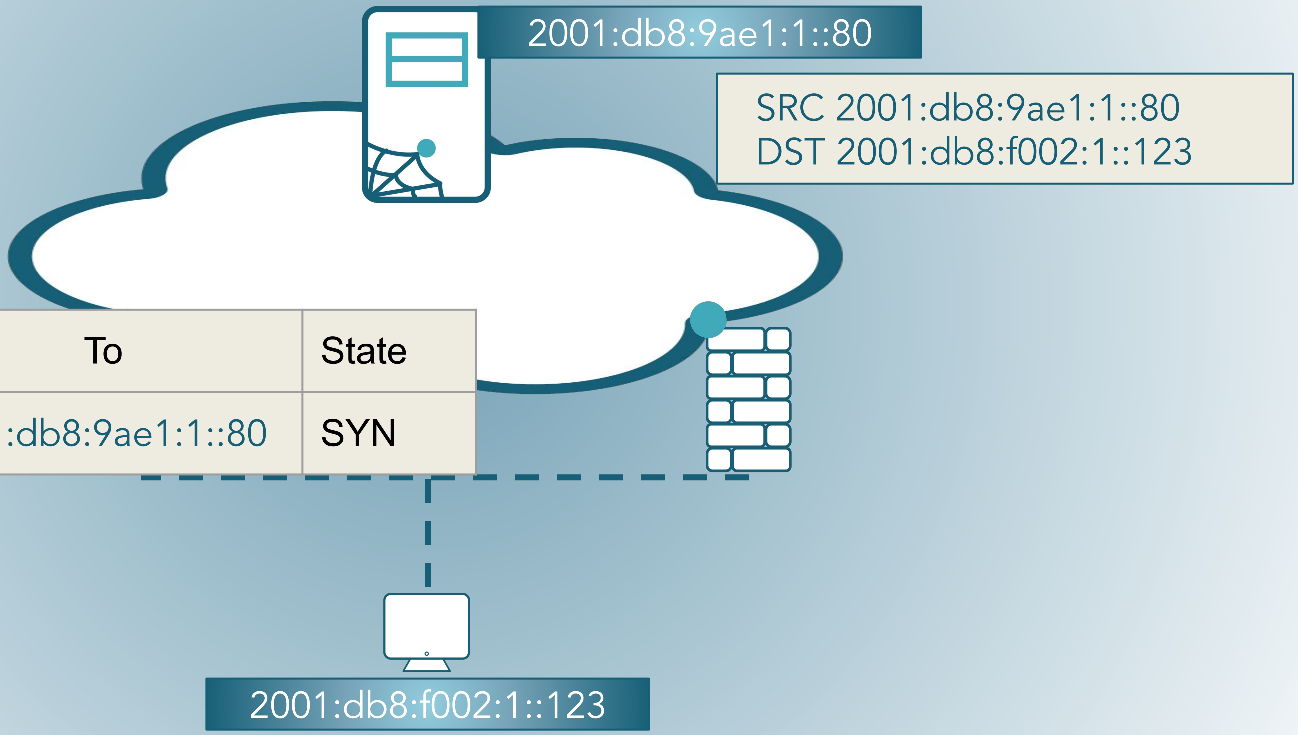
The Multihoming Problem



SRC 2001:db8:9ae1:1::80
DST 2001:db8:f002:1::123

From	To	State
2001:db8:f002:1::123	2001:db8:9ae1:1::80	SYN

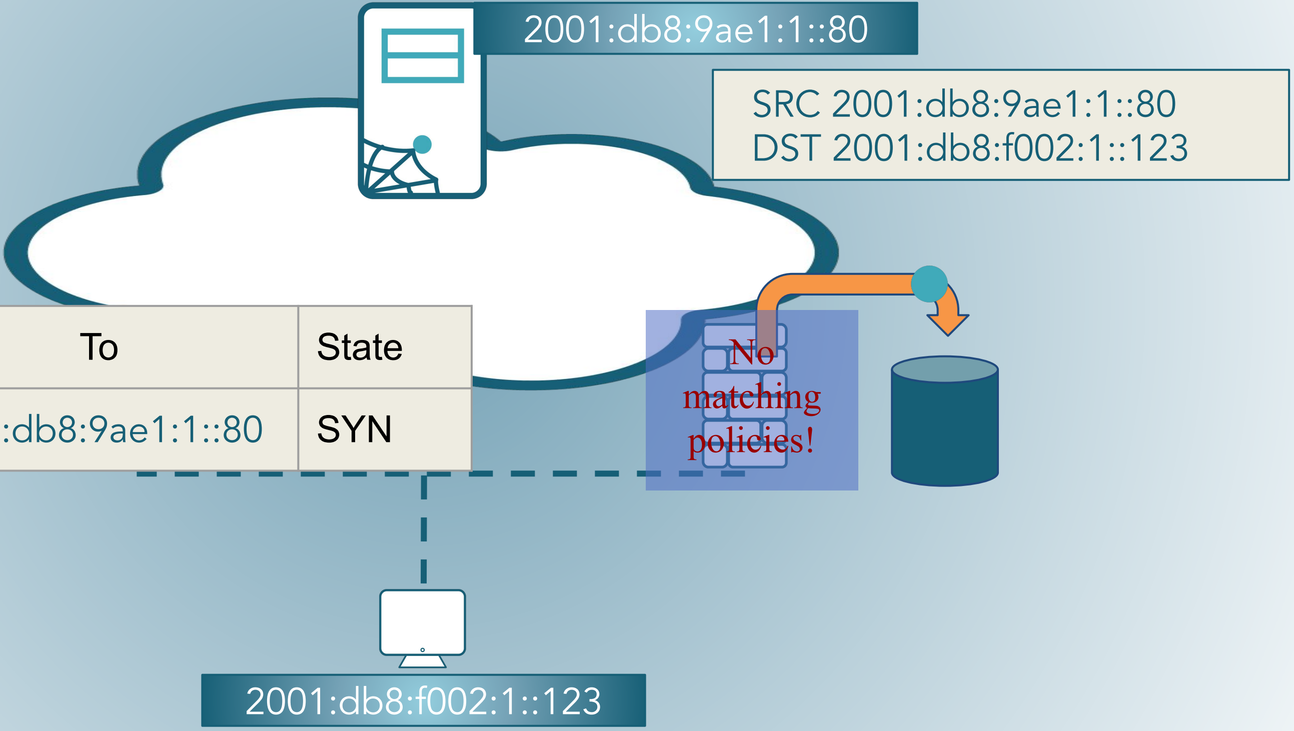
The Multihoming Problem



SRC 2001:db8:9ae1:1::80
DST 2001:db8:f002:1::123

From	To	State
2001:db8:f002:1::123	2001:db8:9ae1:1::80	SYN

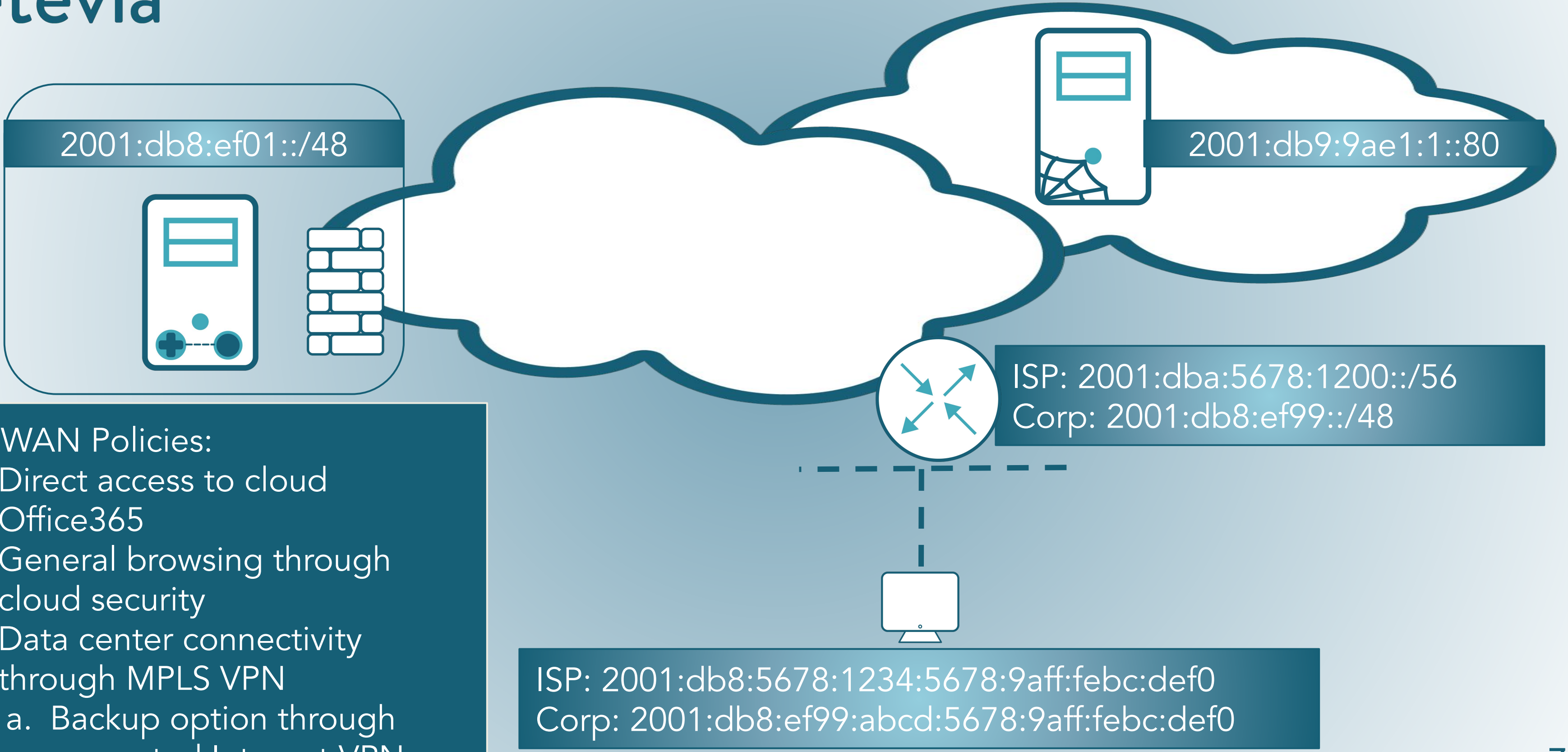
The Multihoming Problem



SRC 2001:db8:9ae1:1::80
DST 2001:db8:f002:1::123

From	To	State
2001:db8:f002:1::123	2001:db8:9ae1:1::80	SYN

Two Networks



2001:db8:ef01::/48

2001:db9:9ae1:1::80

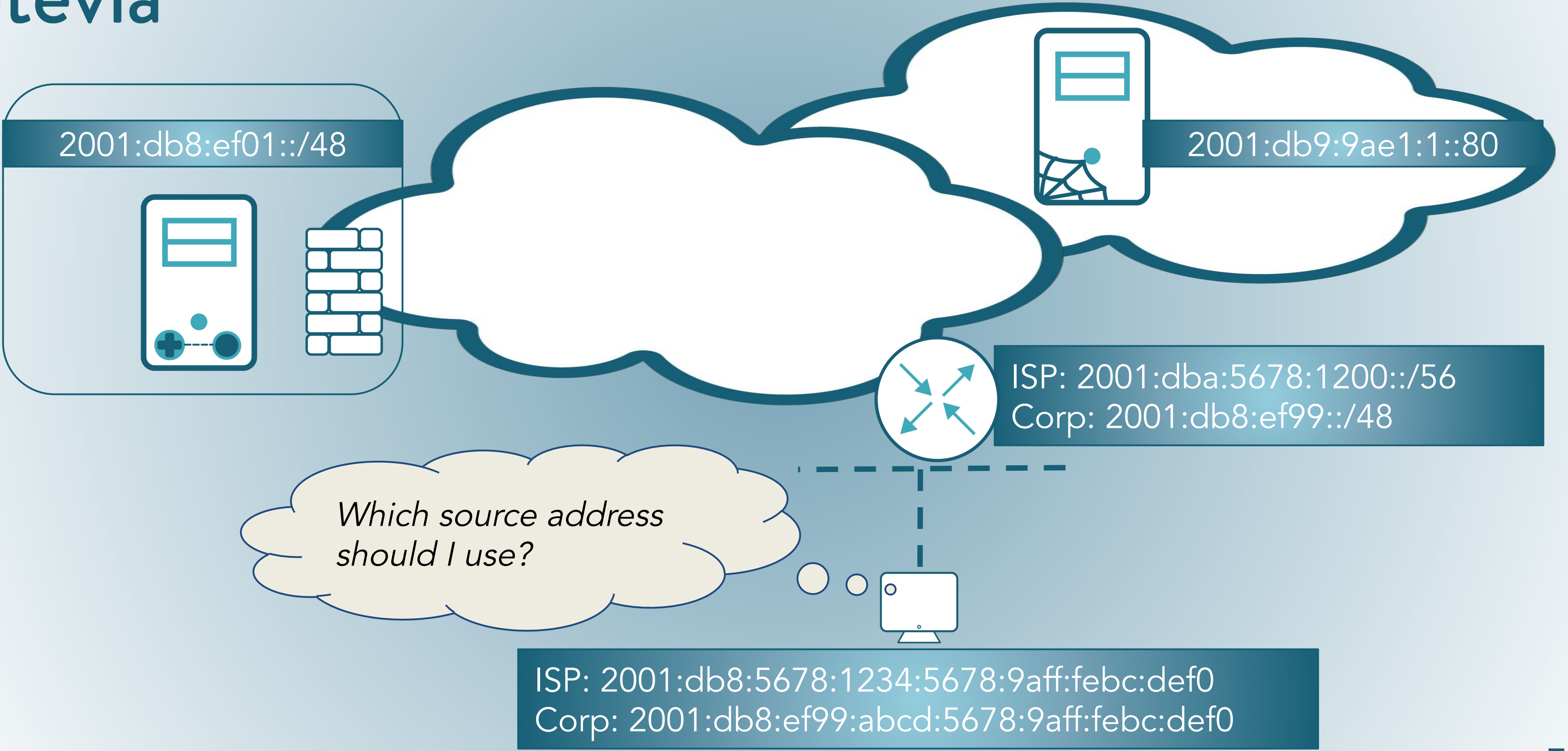
ISP: 2001:dba:5678:1200::/56
Corp: 2001:db8:ef99::/48

ISP: 2001:db8:5678:1234:5678:9aff:febc:def0
Corp: 2001:db8:ef99:abcd:5678:9aff:febc:def0

SD-WAN Policies:

1. Direct access to cloud Office365
2. General browsing through cloud security
3. Data center connectivity through MPLS VPN
   a. Backup option through encrypted Internet VPN

Two Networks



2001:db8:ef01::/48

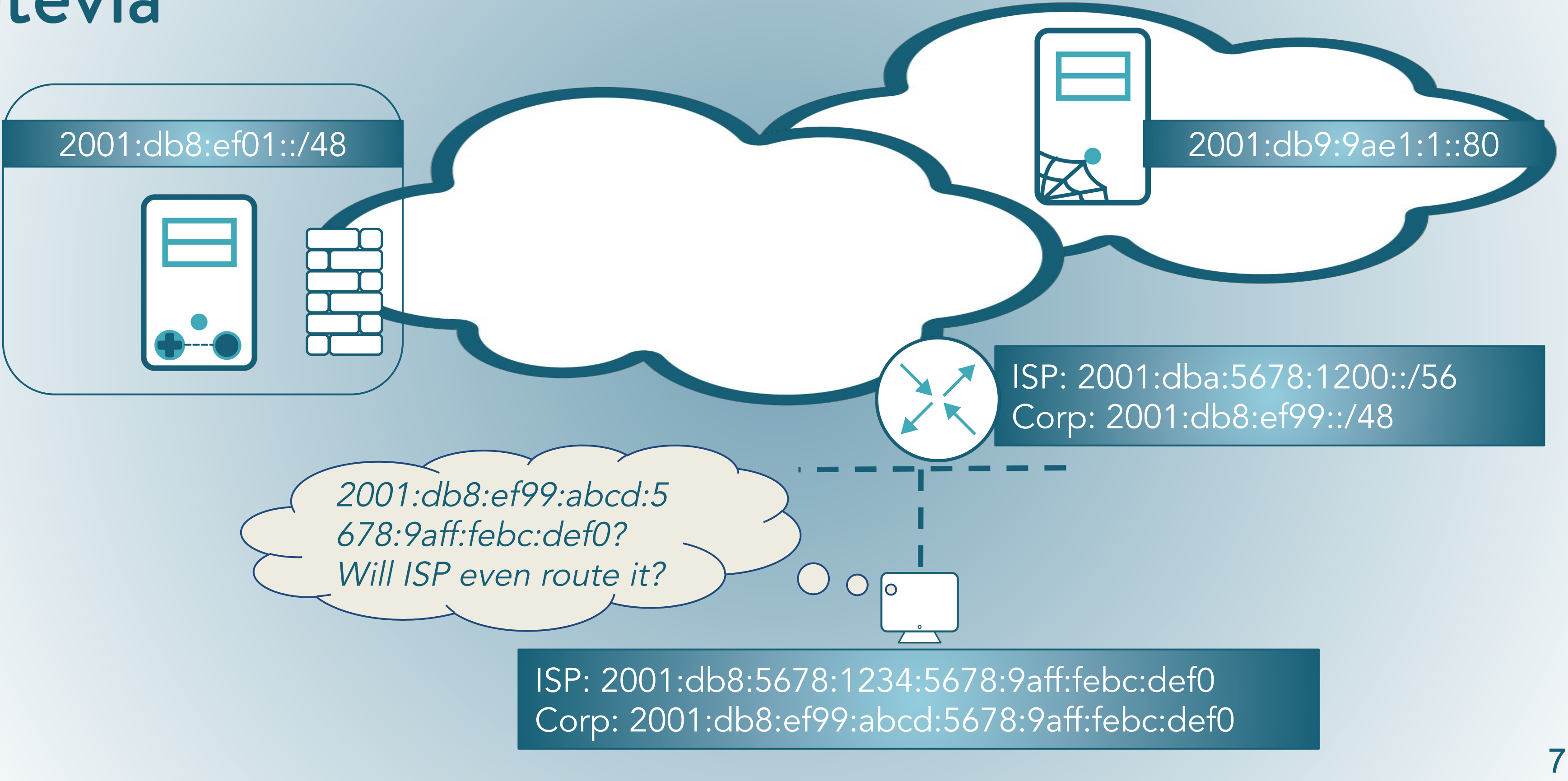
2001:db9:9ae1:1::80

ISP: 2001:dba:5678:1200::/56
Corp: 2001:db8:ef99::/48

Which source address should I use?

ISP: 2001:db8:5678:1234:5678:9aff:febc:def0
Corp: 2001:db8:ef99:abcd:5678:9aff:febc:def0

Two Networks



2001:db8:ef01::/48

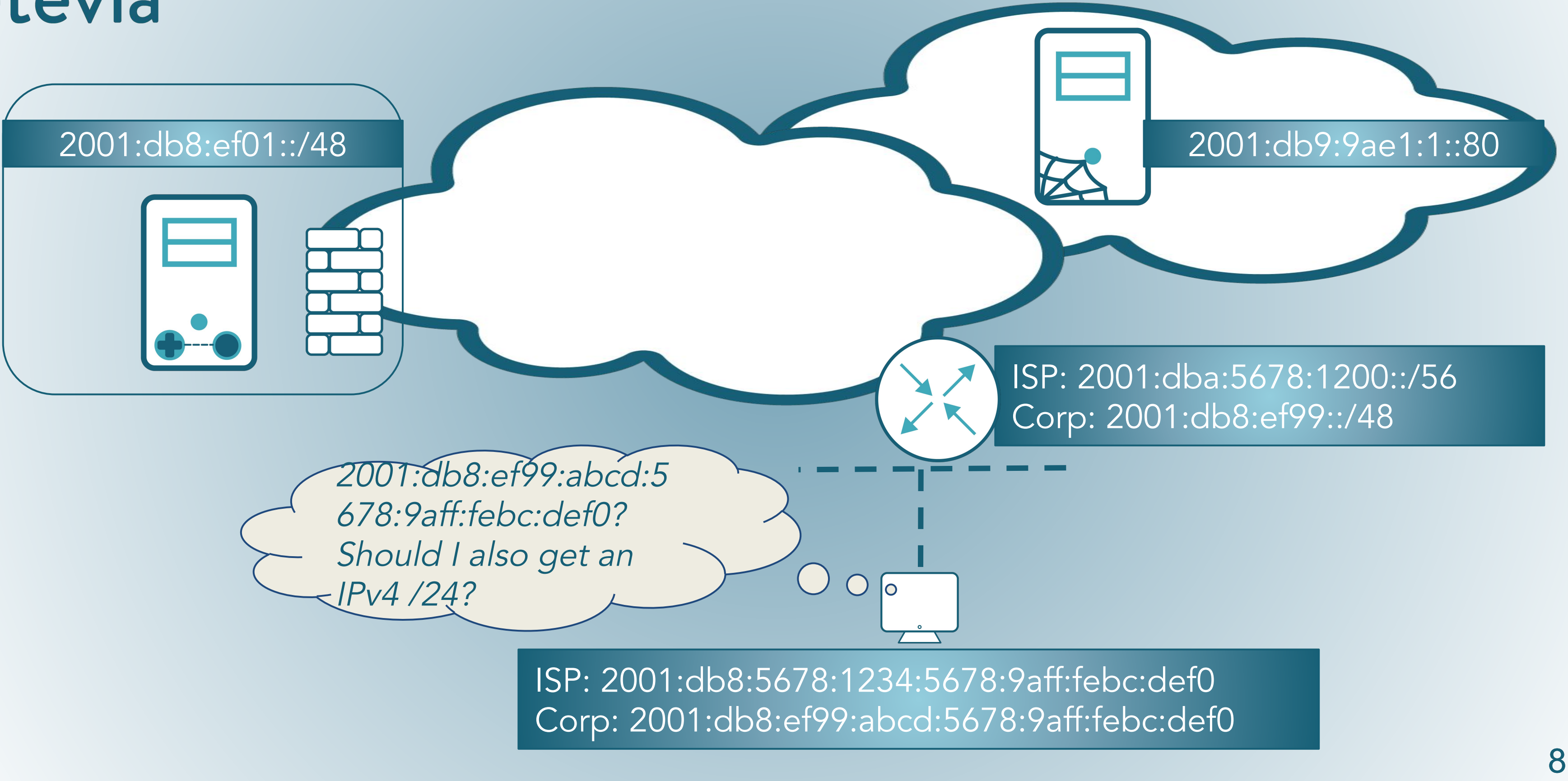
2001:db9:9ae1:1::80

ISP: 2001:dba:5678:1200::/56
Corp: 2001:db8:ef99::/48

2001:db8:ef99:abcd:5678:9aff:febc:def0?
Will ISP even route it?

ISP: 2001:db8:5678:1234:5678:9aff:febc:def0
Corp: 2001:db8:ef99:abcd:5678:9aff:febc:def0

Two Networks



2001:db8:ef01::/48

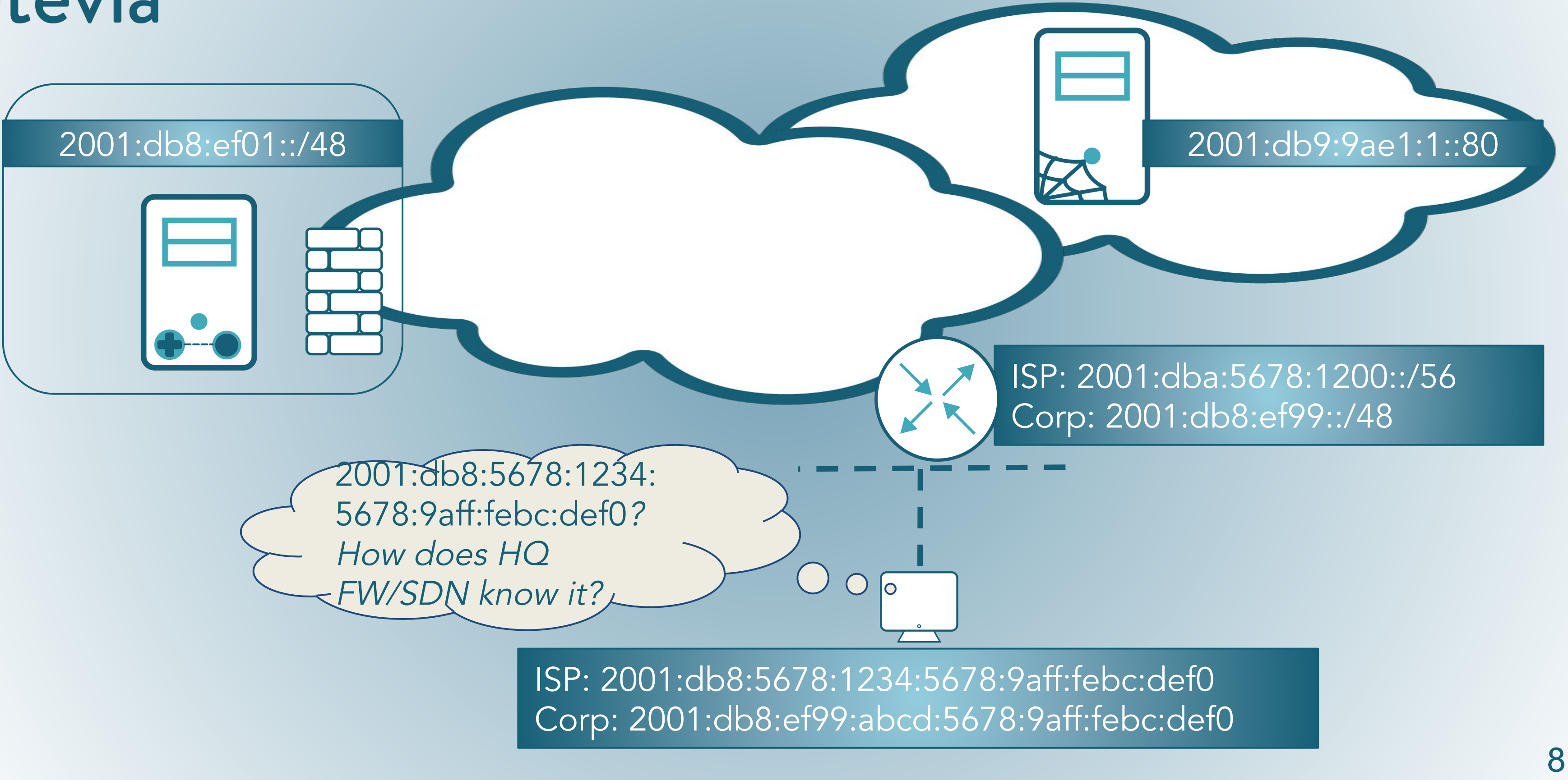
2001:db9:9ae1:1::80

ISP: 2001:dba:5678:1200::/56
Corp: 2001:db8:ef99::/48

2001:db8:ef99:abcd:5678:9aff:febc:def0? Should I also get an IPv4 /24?

ISP: 2001:db8:5678:1234:5678:9aff:febc:def0
Corp: 2001:db8:ef99:abcd:5678:9aff:febc:def0

Two Networks



ISP: 2001:db8:5678:1234:5678:9aff:febc:def0
Corp: 2001:db8:ef99:abcd:5678:9aff:febc:def0

Provisioning Domains

- Provisioning Domain info might include
  - Source address to use in PvD
  - IP addresses of DNS server
  - HTTP proxy (if any)
  - DNS suffixes for the network
  - Default gateway address

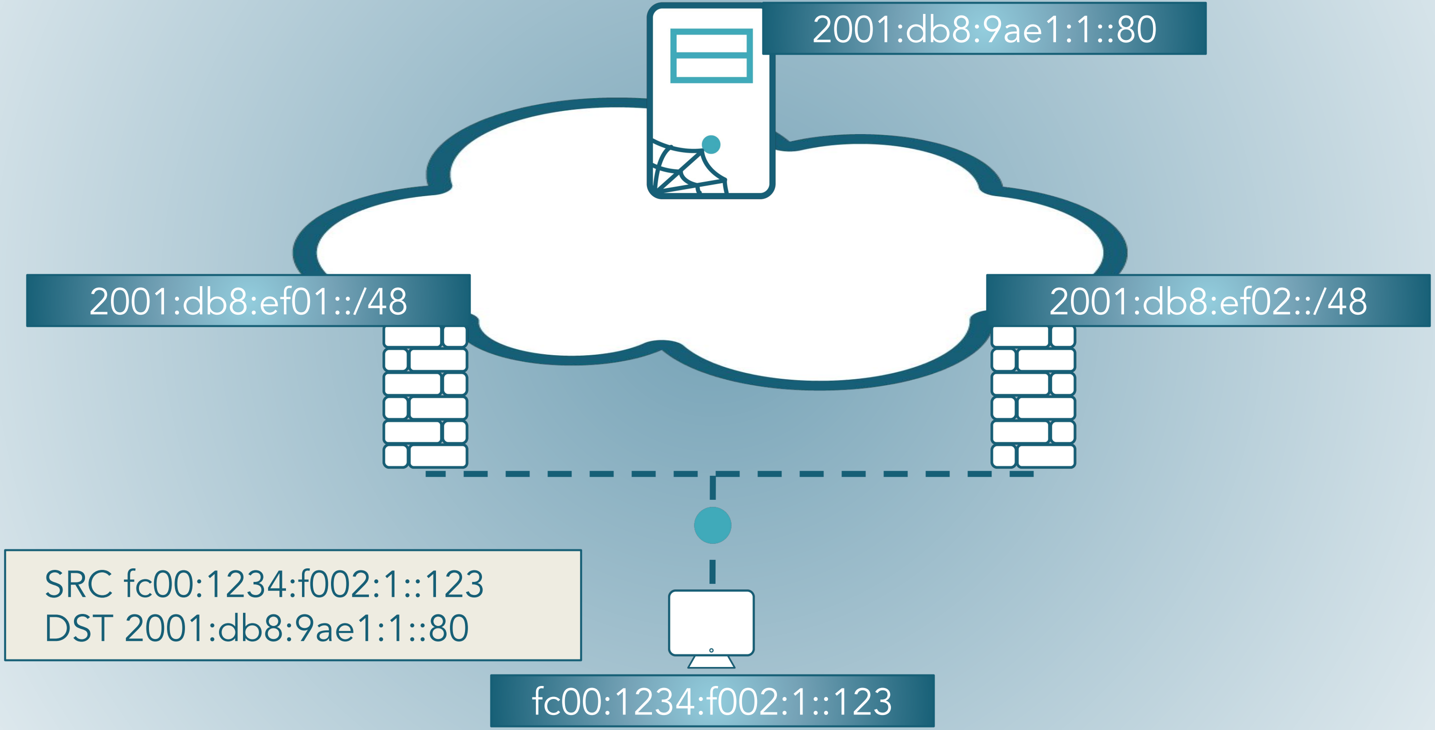
Source Address Selection

1. Avoid unusable destinations
2. Prefer matching scope
3. Avoid deprecated addresses
4. Prefer home address
5. Prefer matching label
6. Prefer higher precedence
7. Prefer native transport
8. Prefer smaller scope
9. Use longest matching prefix
10. Leave order unchanged

Sorry - this problem isn't solved yet

See https://tools.ietf.org/html/draft-ietf-intarea-provisioning-domains-02 for leading candidate (identify PvD with a FQDN in the RA)

Network Prefix Translation



2001:db8:9ae1:1::80

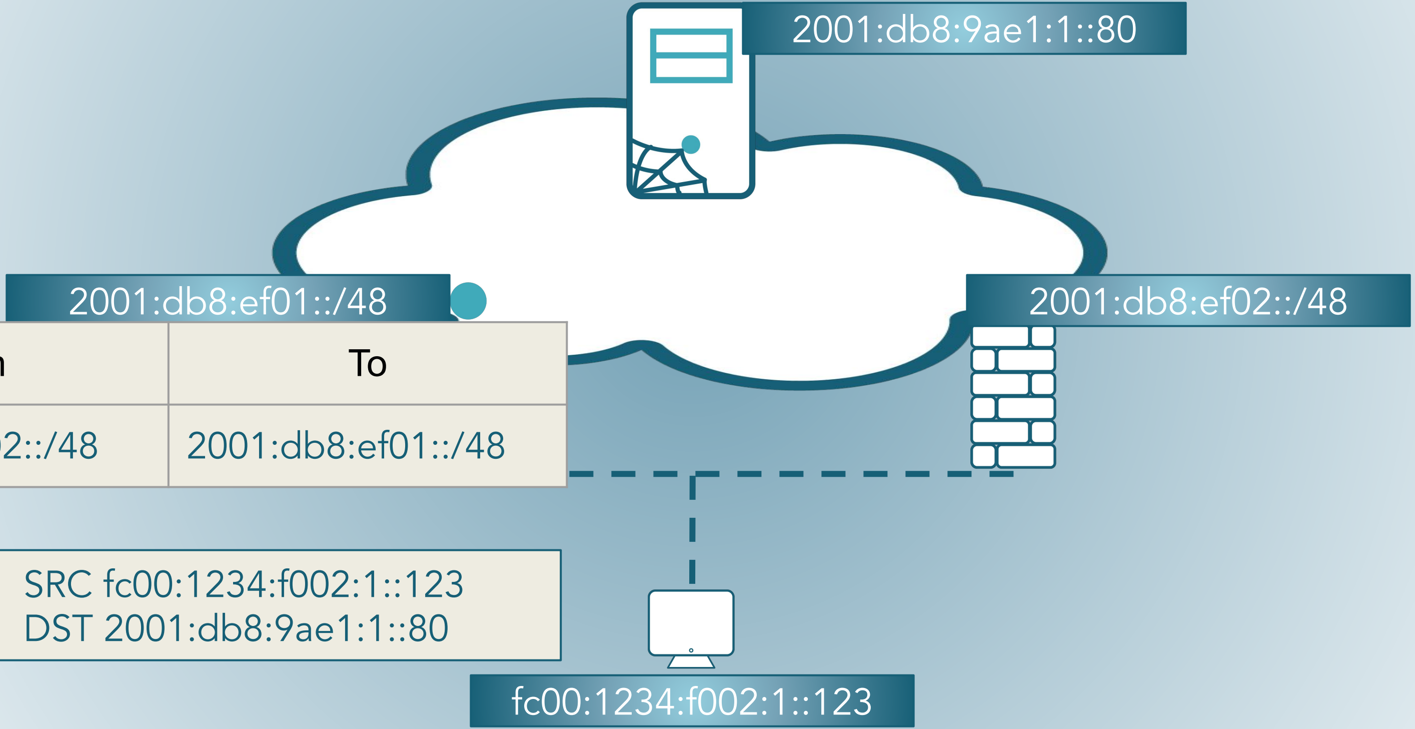
2001:db8:ef01::/48

2001:db8:ef02::/48

SRC fc00:1234:f002:1::123
DST 2001:db8:9ae1:1::80

fc00:1234:f002:1::123

Network Prefix Translation



2001:db8:9ae1:1::80

2001:db8:ef01::/48

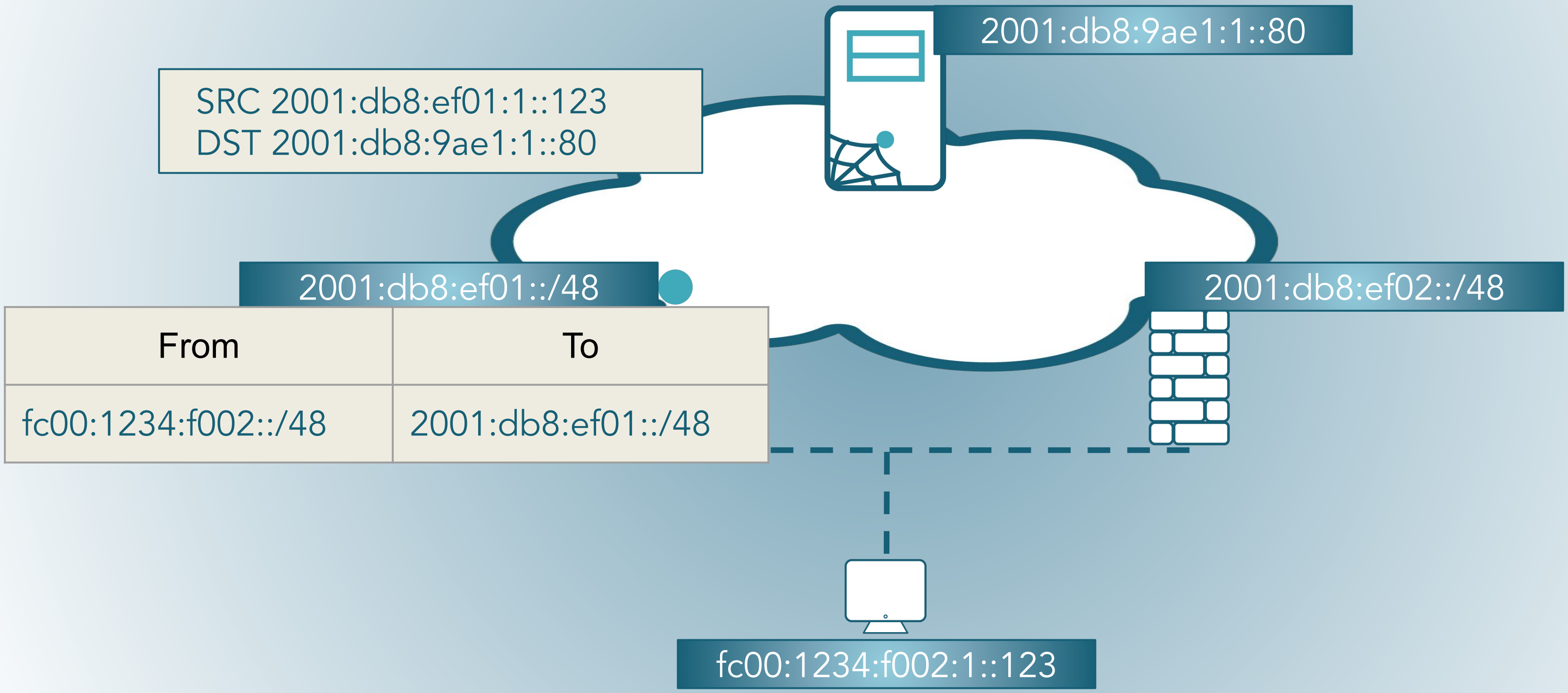
2001:db8:ef02::/48

fc00:1234:f002:1::123

From	To
fc00:1234:f002::/48	2001:db8:ef01::/48

SRC fc00:1234:f002:1::123
DST 2001:db8:9ae1:1::80

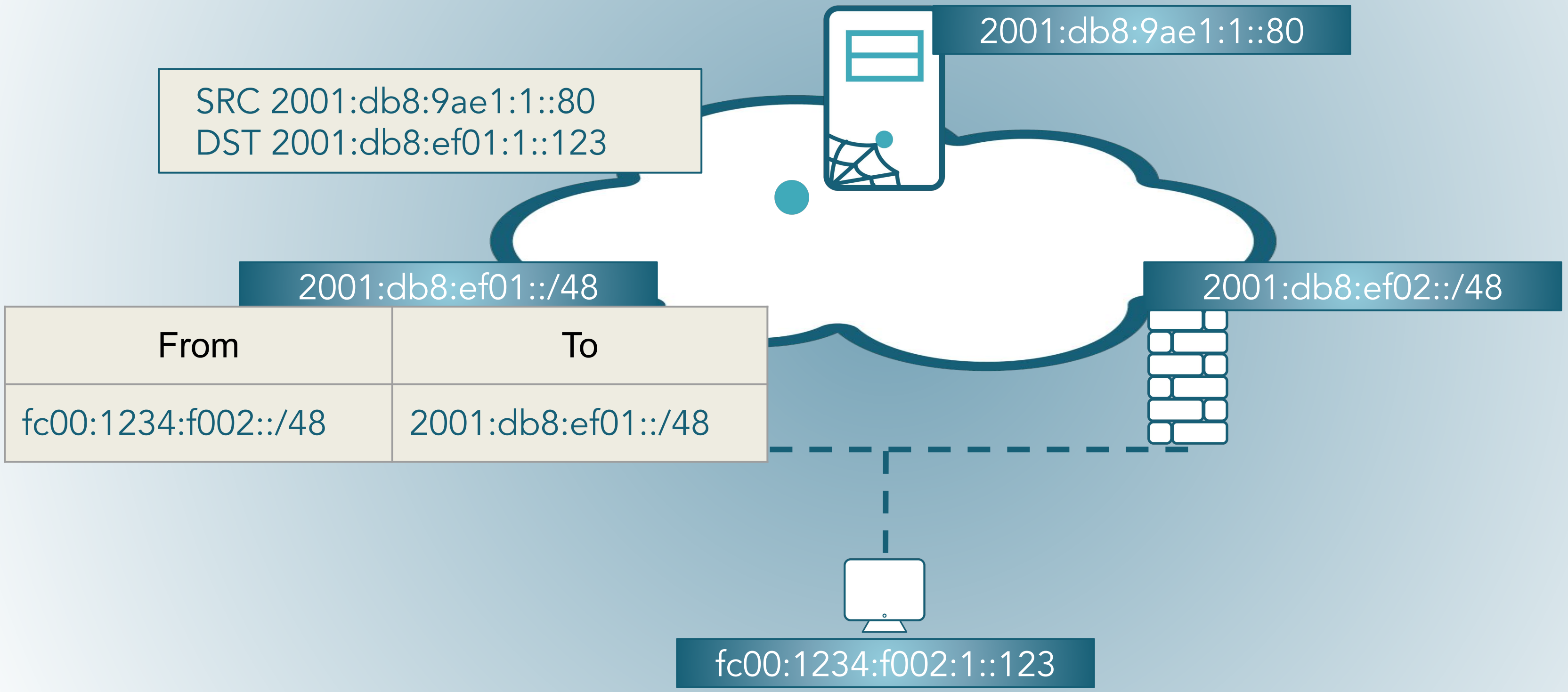
Network Prefix Translation



SRC 2001:db8:ef01:1::123
DST 2001:db8:9ae1:1::80

From	To
fc00:1234:f002::/48	2001:db8:ef01::/48

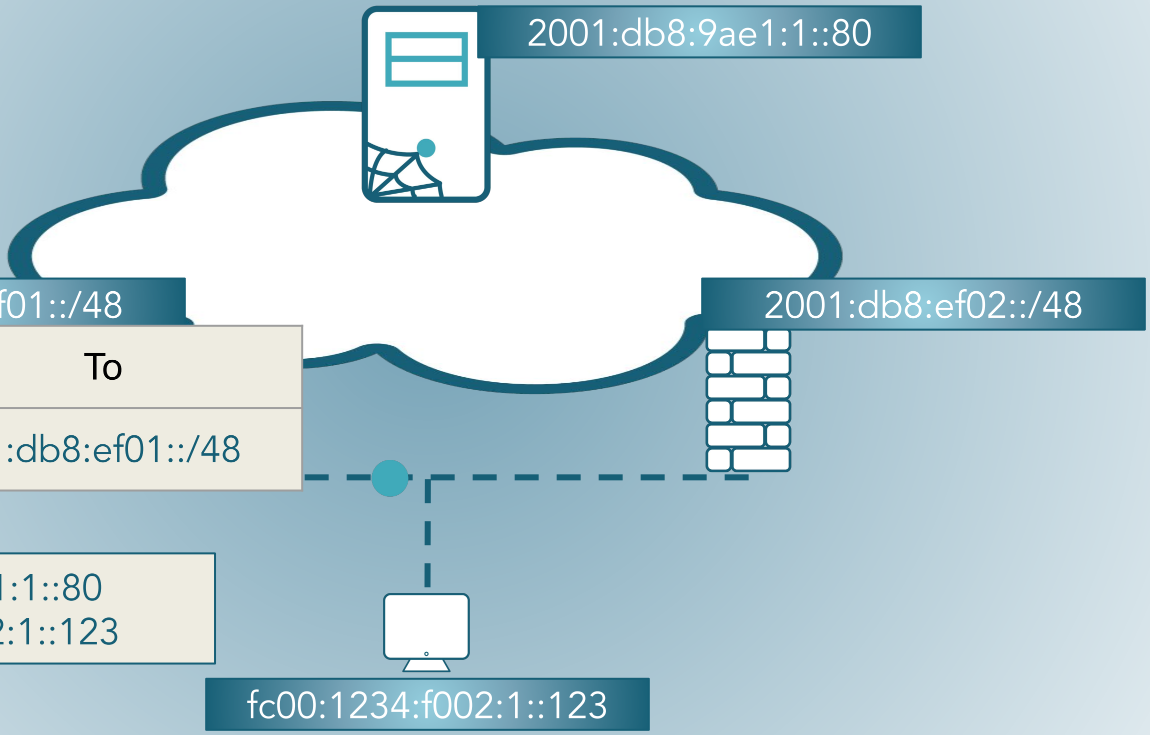
Network Prefix Translation



SRC 2001:db8:9ae1:1::80
DST 2001:db8:ef01:1::123

From	To
fc00:1234:f002::/48	2001:db8:ef01::/48

Network Prefix Translation



From	To
fc00:1234:f002::/48	2001:db8:ef01::/48

SRC 2001:db8:9ae1:1::80
DST fc00:1234:f002:1::123

Connecting the Office

What else should I worry about?

Other Obstacles

- Additional considerations for IPv6 deployment (ISPs, devices, web, and what can be done)
- ·   If not otherwise covered, a summary of reports from Cisco and Microsoft's IPv6-only experiences

Retevia

Discussion

Retevia